Technical Memorandum

AN EIGHT-NEIGHBOR FILTER FOR LARSYS

Prepared By

Lockheed Electronics Company, Inc.
Aerospace Systems Division
Houston, Texas

Contract NAS 9-12200

For

EARTH OBSERVATIONS DIVISION

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

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FIGURES

1. SPATIAL FILTERING

Spatial filtering was originally developed to eliminate misclassifications of pixels. The four-neighbor filter was developed and tested by Van Roon and Lynn (ref. 1) and was incorporated into the EOD-LARSYS program at the Johnson Space Center (ref. 2).

Coincidentally, two special filtering problems arose in the screwworm eradication project of NASA's Health Applications Office. Both involved an automatic classification procedure (ref. 3) for converting zonal maps on paper to properly coded digital tapes. Misclassification of pixels in homogeneous zones required some kind of filtering technique, and the serious classification problems at interzone boundaries also required a powerful filter.

An eight-neighbor filter as described in this report fills these needs, differing from the Van Roon and Lynn filter in two important aspects. First, it is based on eight neighbors rather than four, and the number of these neighbors defining a misclassification can be set from three to eight. Second, it can be applied repeatedly.

This report demonstrates the use of this new filter. Since few technical details are presented, the reader interested in greater detail should consult reference 3, which presents more details of the program.

2. A DESCRIPTION OF THE FILTER

The operation of the eight-neighbor filter is described at length in reference 3. Basically, the eight-neighbors of each pixel are examined for class. If the filter options specify three neighbors, then the pixel is replaced by the class first found three times in an orderly search of the neighbors.

For most uses, the first class found three times in an ordered search of the eight neighbors appears to be the most appropriate for reclassification of a given pixel. Classification of real images, such as Landsat, benefit from two or three consecutive applications of the filters. Artificial images require about five applications of the same filter to eliminate misclassified boundaries.

3. APPLICATION OF THE FILTER

Figure 1, in black and white, shows an image to be digitized. Figure 3 shows a symbol map from a machine classification of a hand-painted zone map. Note that in figure 3A (the classified non-filtered image) several classifications are defective since the zones must be homogeneous; all borders seem to be defective. The remaining figures show how various filter combinations perform a homogenization of the zones and edges.

It should be noted that the image studied here was digitized by the table scanner of the Image-100 computer at JSC in building 17. This scanner is little more sophisticated than a television receiver. Illumination of opaque images is primitive, based on two photoflood lamps, which are very uneven in illumination. If a good scanner with good illumination were used, classification results would be much cleaner.

The most urgent use of the filter in the digitization of zonal maps involves the elimination of misclassifications at the boundaries between painted zones. Misclassifications occur here because of pixels that are mixed because of differences in relief in the interzonal areas which cause shadows, the admixture of paints, and for many other reasons. Figures 2A and 2B show the magnitude of the problem in a typical case.

The cleaning of boundaries requires a multiple application of the filter, as shown in the various cases presented in these figures. It is apparent that the filters must usually be applied several times before the boundaries are distinct.

This type of use carries significant dangers for use with natural images. For the artificial zonal images for which this capability was developed, the exact location of the boundary was much less important than having a sharp boundary between zones.

Nonsharp boundaries will have improperly classified pixels whose values would have no relation to either of the two adjoining zones.

Multiple application of the filter can cause boundaries to move, and this would normally be a distortion of the proper classifications of a natural image. For this reason, indiscriminate multiple use of this filter should be strongly discouraged.

Figures A-1 and B-1 document the application of this filter system to different non-synthetic images. In figure A-1 the filter system was applied to a zone discriminator using composite ITOS images (ref. 4). Figure B-1 demonstrates its application to cluster analysis of a Landsat image.

4. CONCLUSIONS

The new eight-neighbor filter has its first use in cleaning zones and sharpening boundaries during the digitization of hand-painted zone maps. It has also shown value in making computer-based vegetation zones more homogeneous, as they are known to be. Its application to classification of natural images, such as Landsat or other multispectral imagery, is demonstrated in appendix B. Indications are that it will be useful if judiciously applied, but that without care it can lead to gross errors if multiple applications are made.

5. REFERENCES

1. Van Roon, D. L.; and Lynn, M. S.: Use of Spatial Information in Classification of Remotely Sensed Data. Rice University, Houston, Texas, May 1973.

2. Minter, Ruth; Gardner, C. T.; Wills, B. E.; and Corbett, B. W.: User Documentation EOD-LARSYS, Earth Observation Divisions Version of the Laboratory for Applications of Remote Sensing System Program Q619, LEC-3984, 1975.

3. Boston, Sydney; and Giddings, L. E.: Technical Memorandum Digitizing Zone Maps, Using Modified LARSYS Program. JSC-10757, LEC-7498, April 1976.

4. Arp, G.; Forsberg, F.; Giddings, L.; and Phinney, D.: System Development of the Screwworm Eradication Data System (SEDS) Algorithm. JSC-10965, LEC-7646, January 1976.

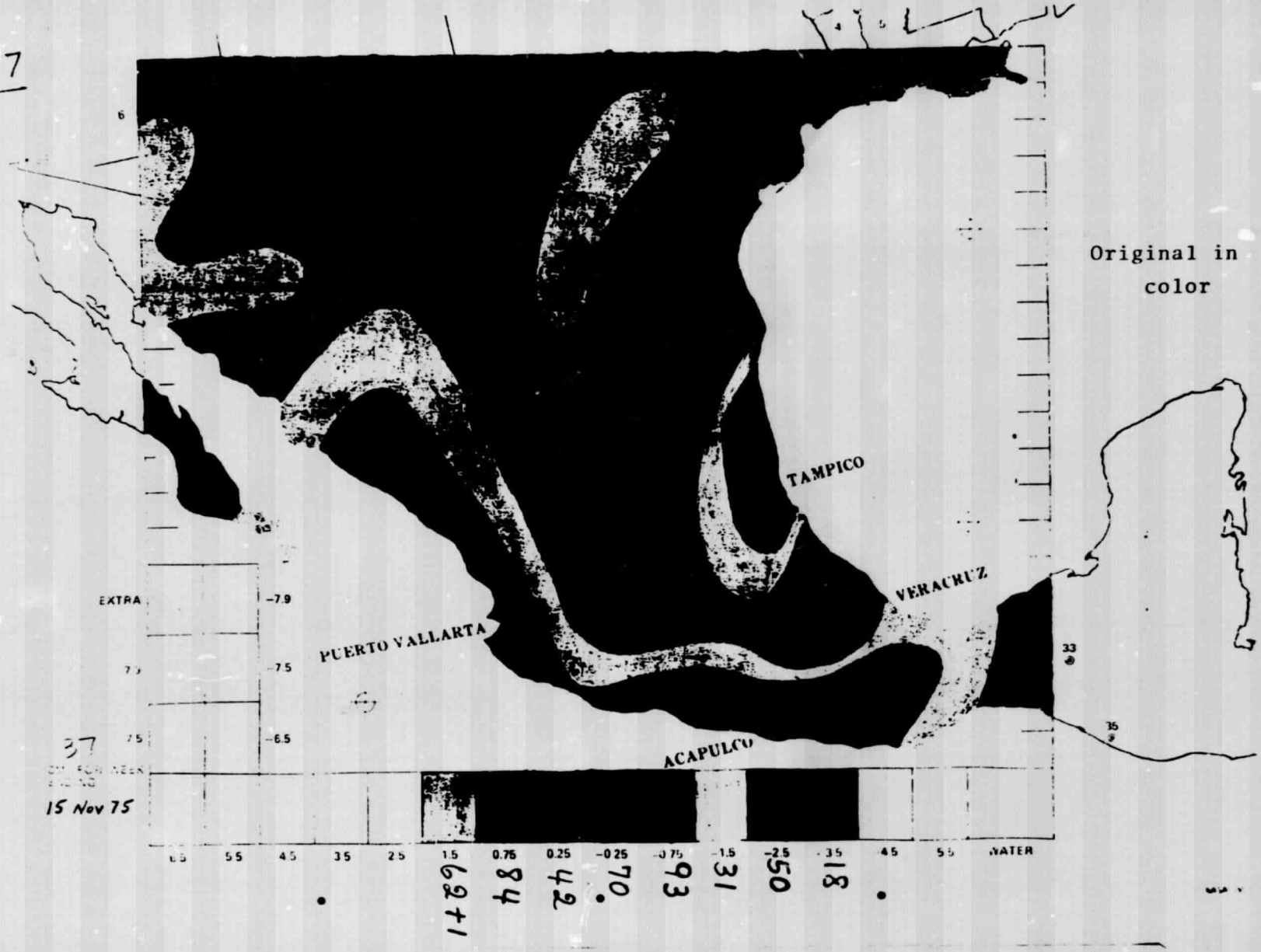


Figure 1. – An artificial image to be classified and filtered.

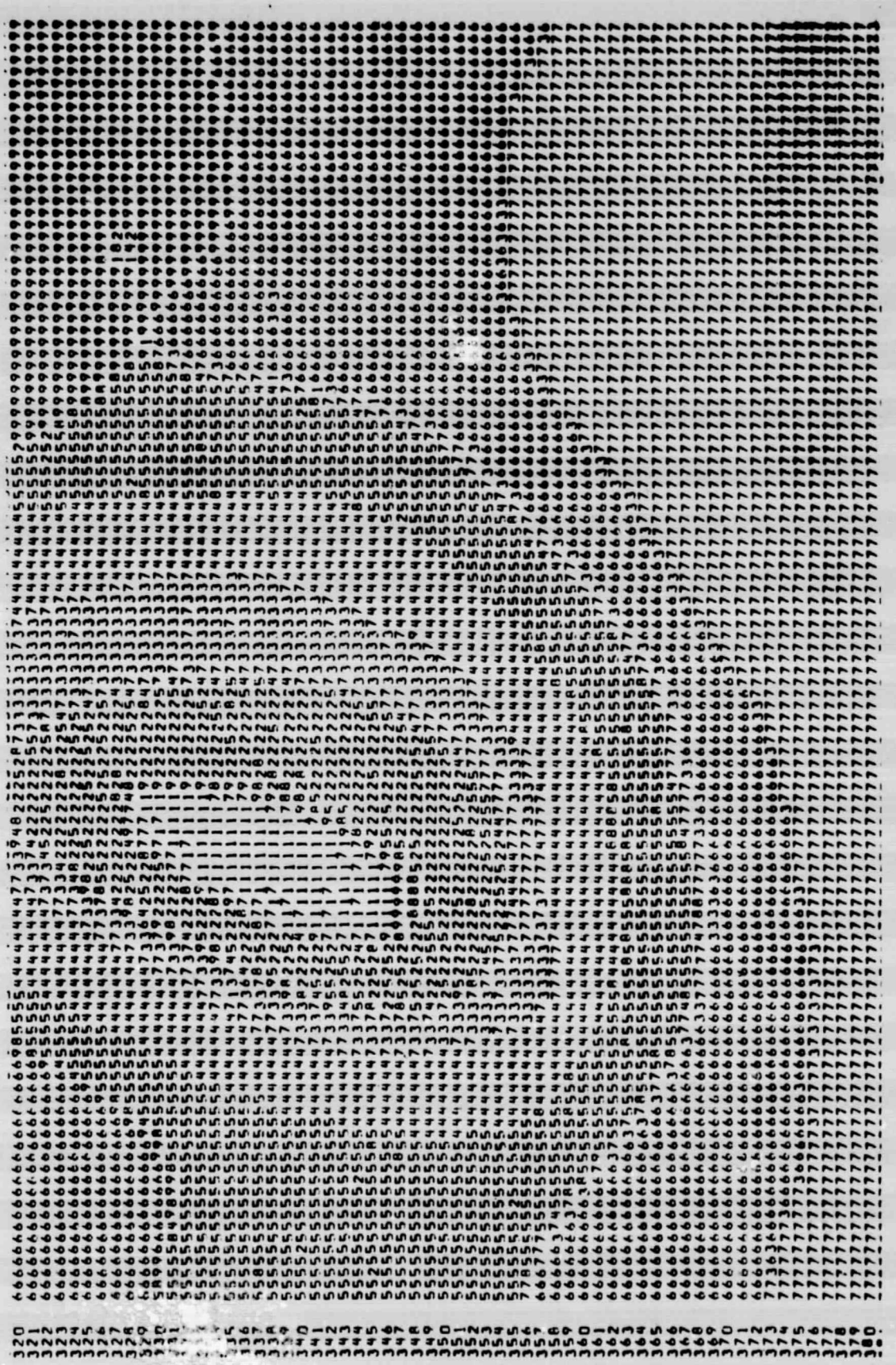


Figure 2a.— Classification of a portion of figure 1 without thresholding.

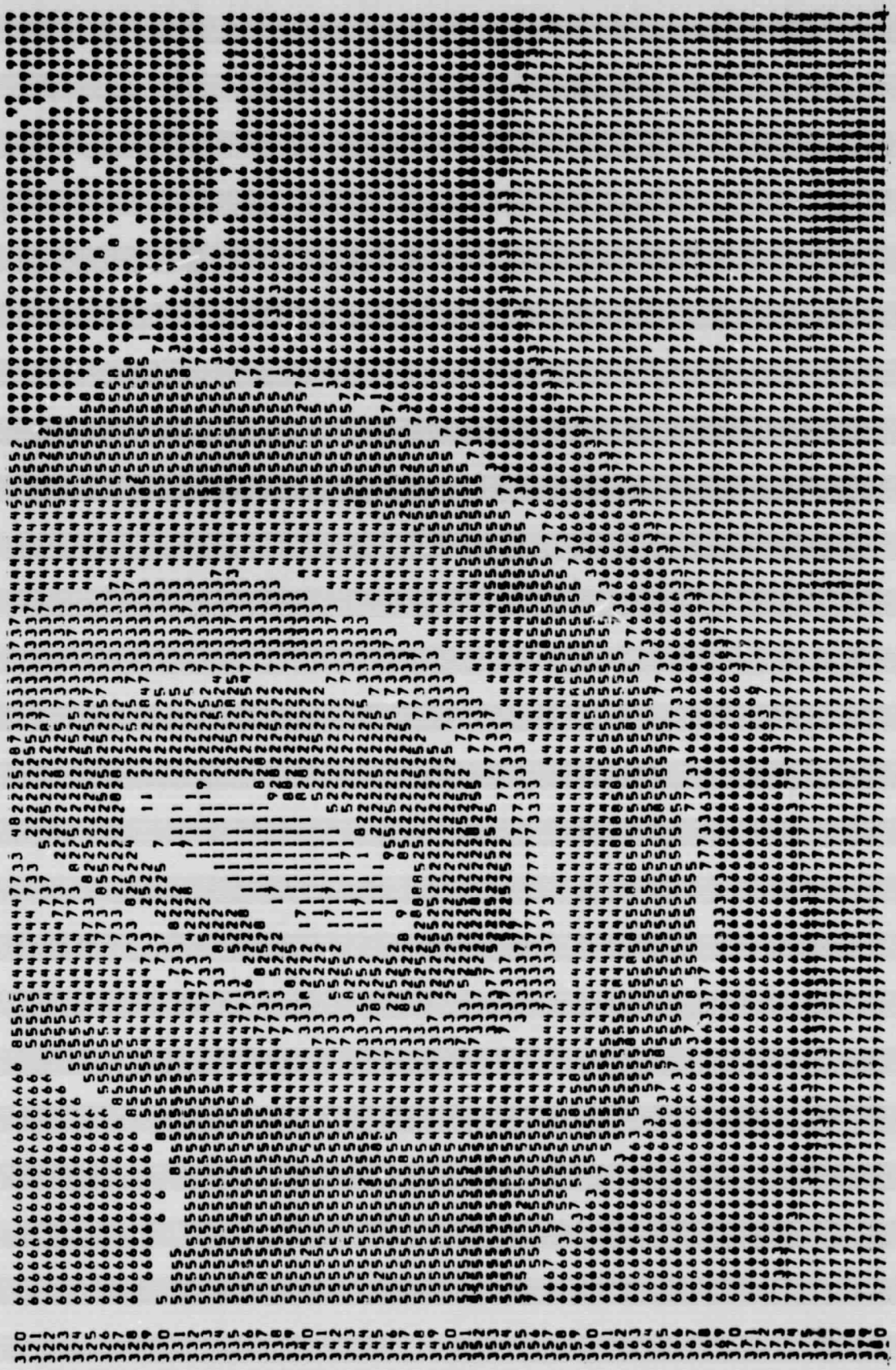


Figure 2b.— Classification of figure 1 with arbitrary threshold value of 50.

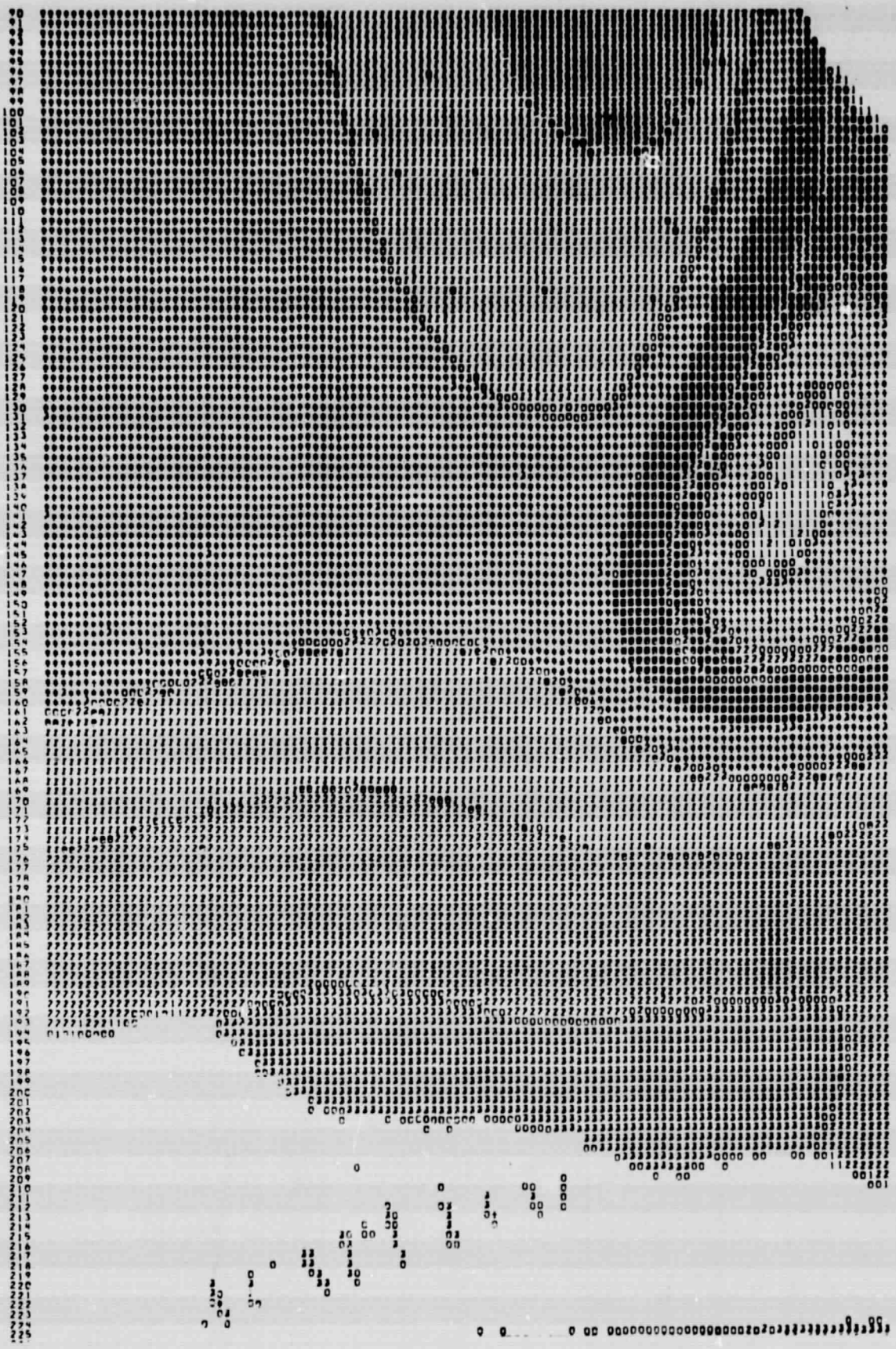


Figure 3a.— Classification results for the artificial image, thresholded before application of three-neighbor filter. (Thresholded pixels are represented by zeroes.)

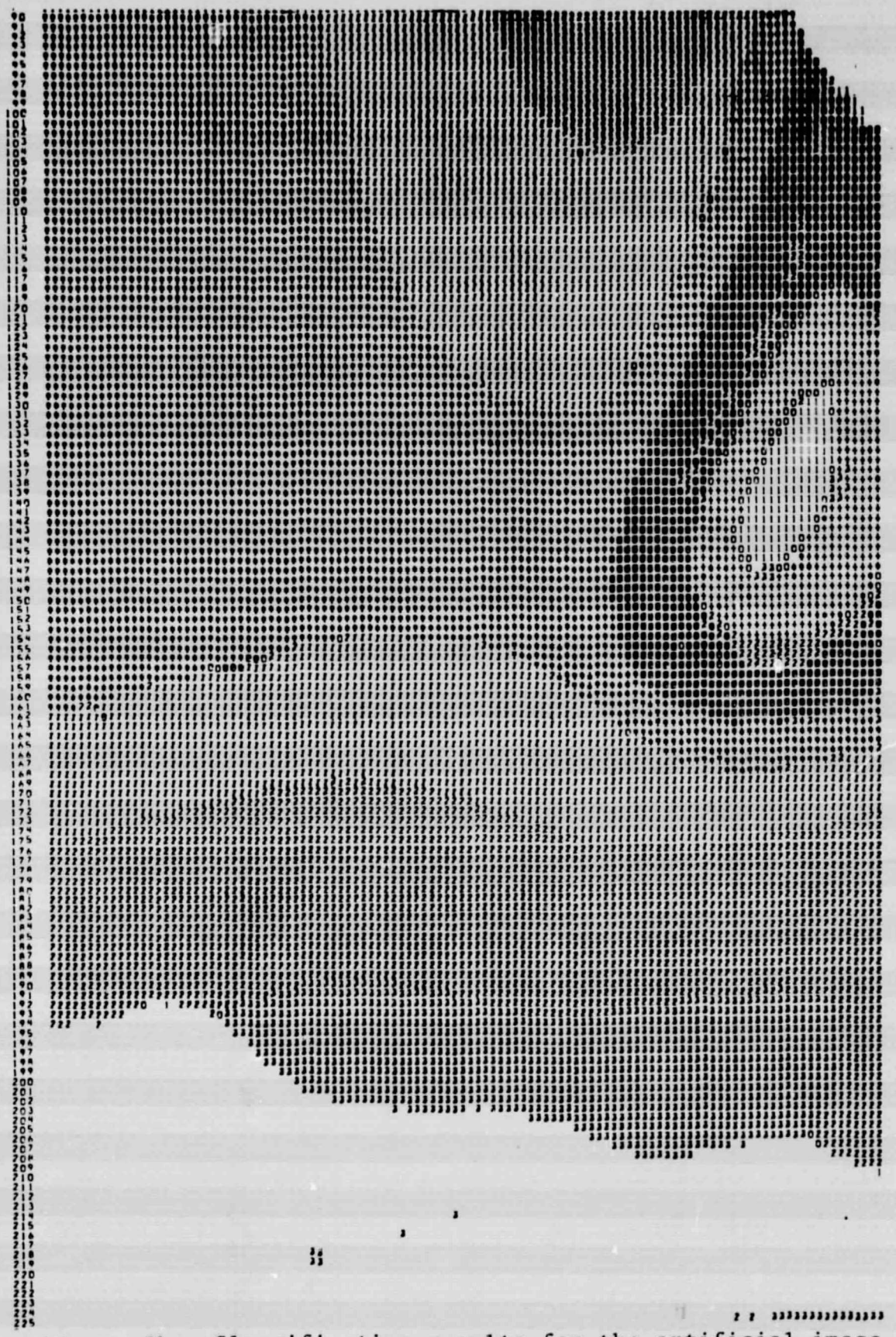


Figure 3b.— Classification results for the artificial image, thresholded, with application of three-neighbor filter: Filter applied once.

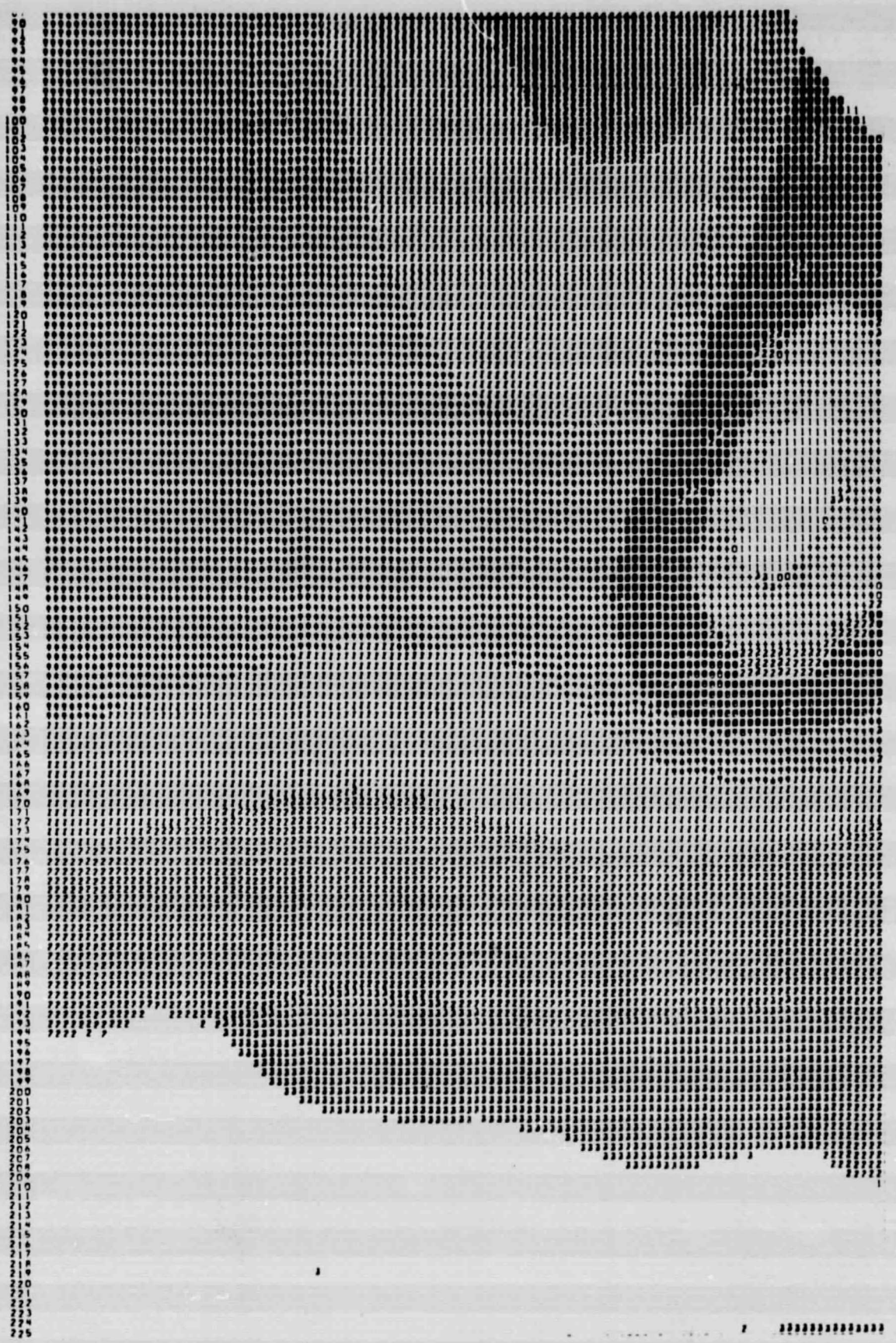


Figure 3c.— Classification results for the artificial image, thresholded, with application of three-neighbor filter: Filter applied twice.

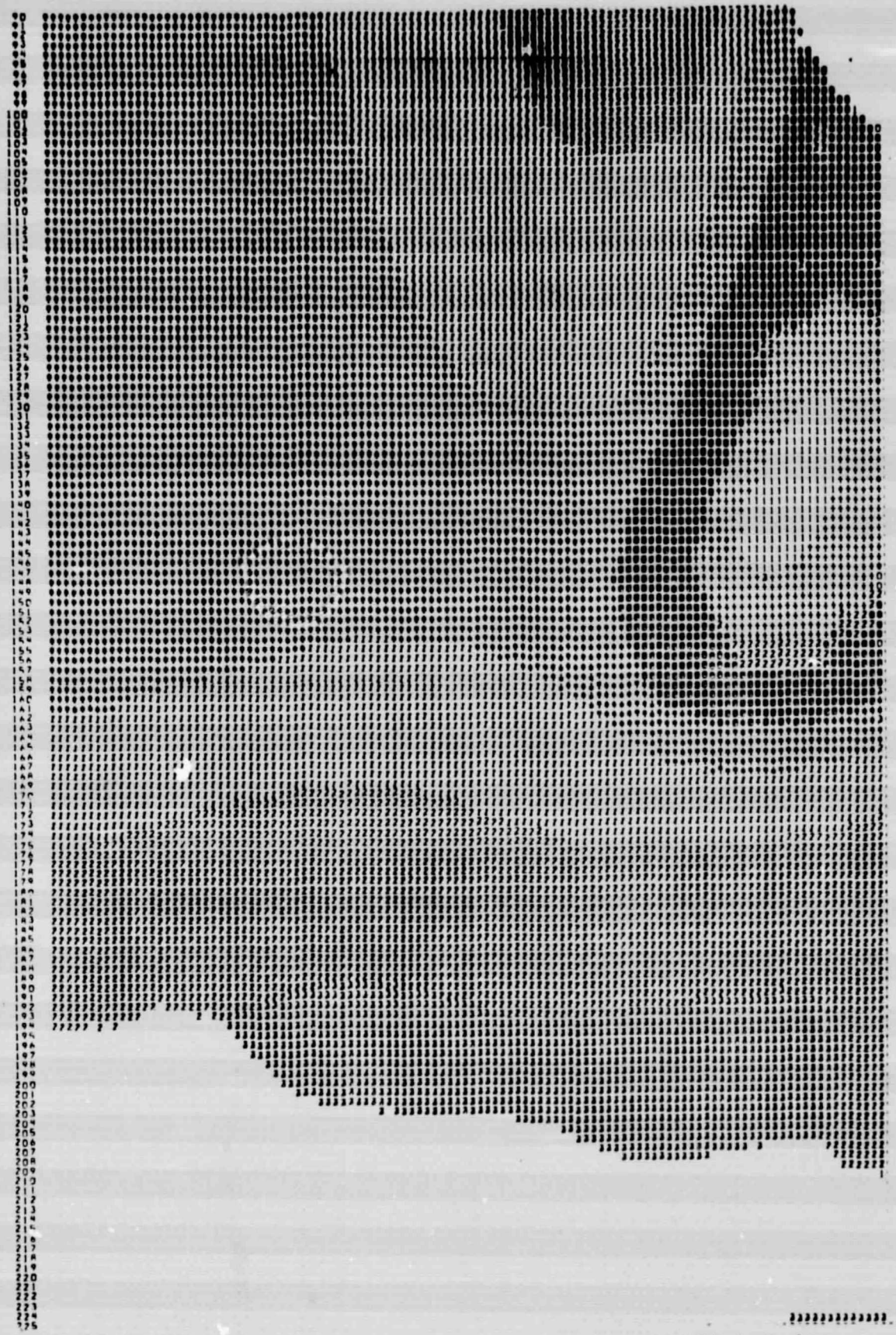


Figure 3d.– Classification results for the artificial image, thresholded, with application of three-neighbor filter: Filter applied three times.

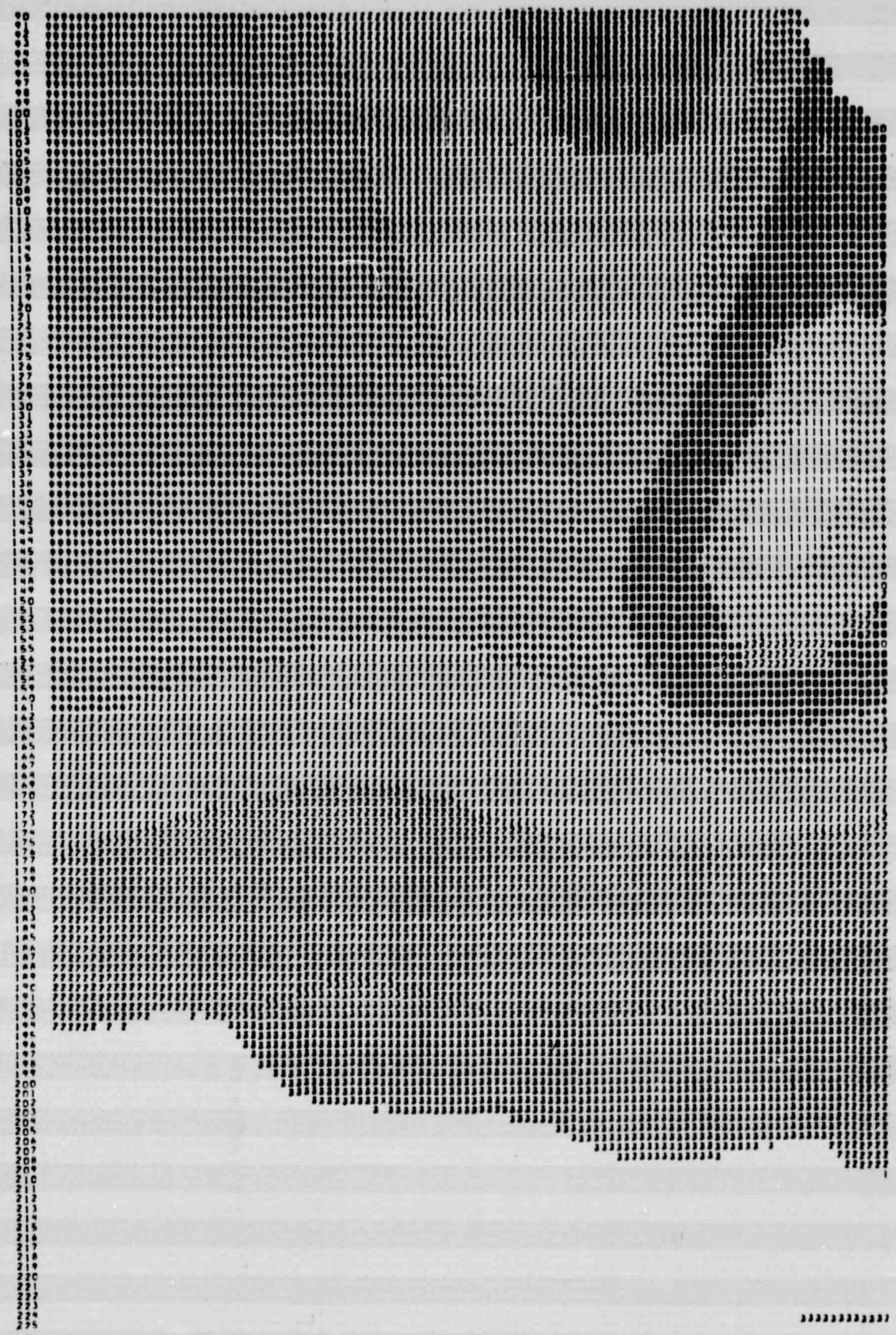


Figure 3e.– Classification results for the artificial image, thresholded, with application of three-neighbor filter: Filter applied four times.

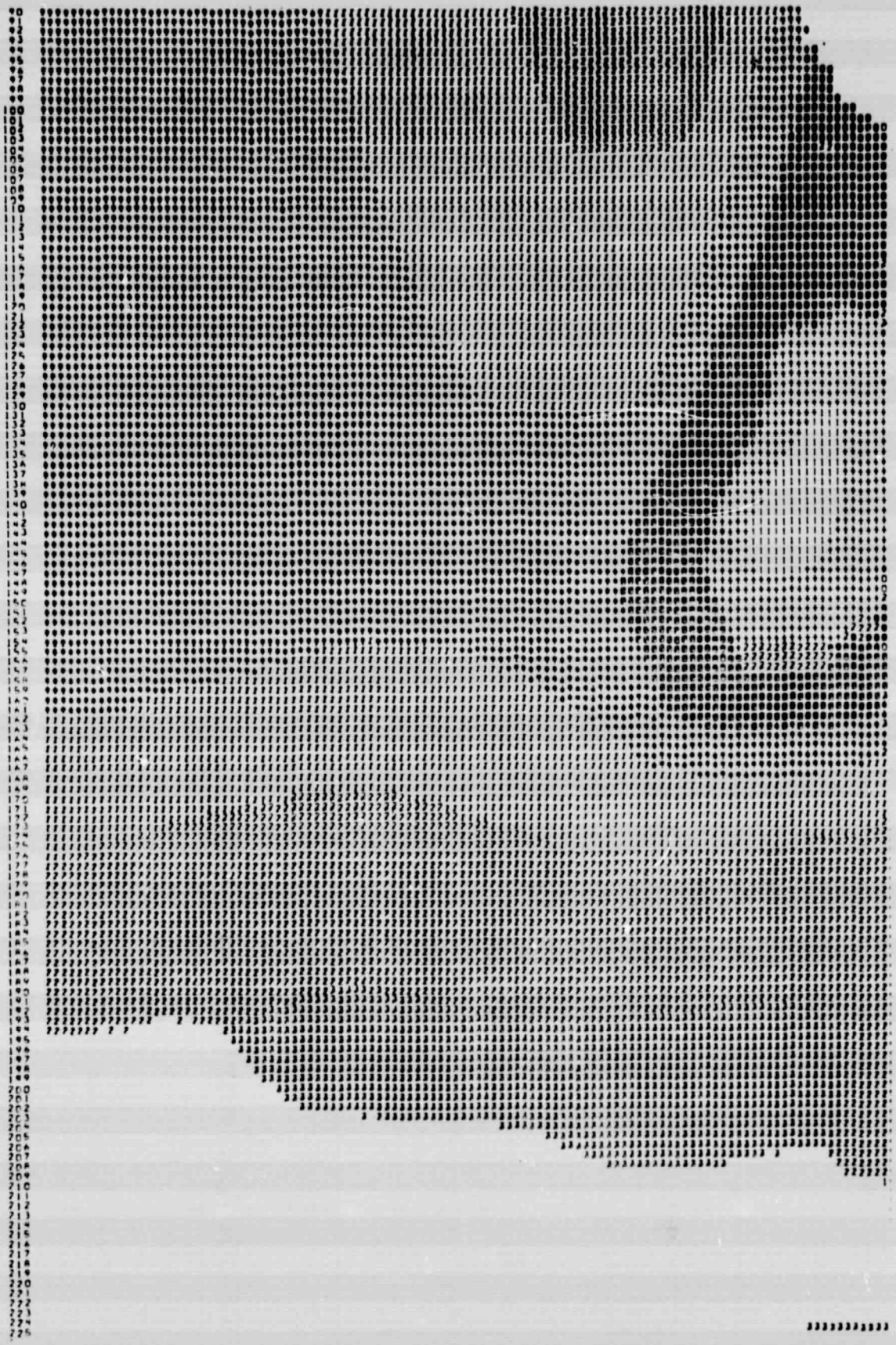


Figure 3f.– Classification results for the artificial image, thresholded, with application of three-neighbor filter: Filter applied five times.

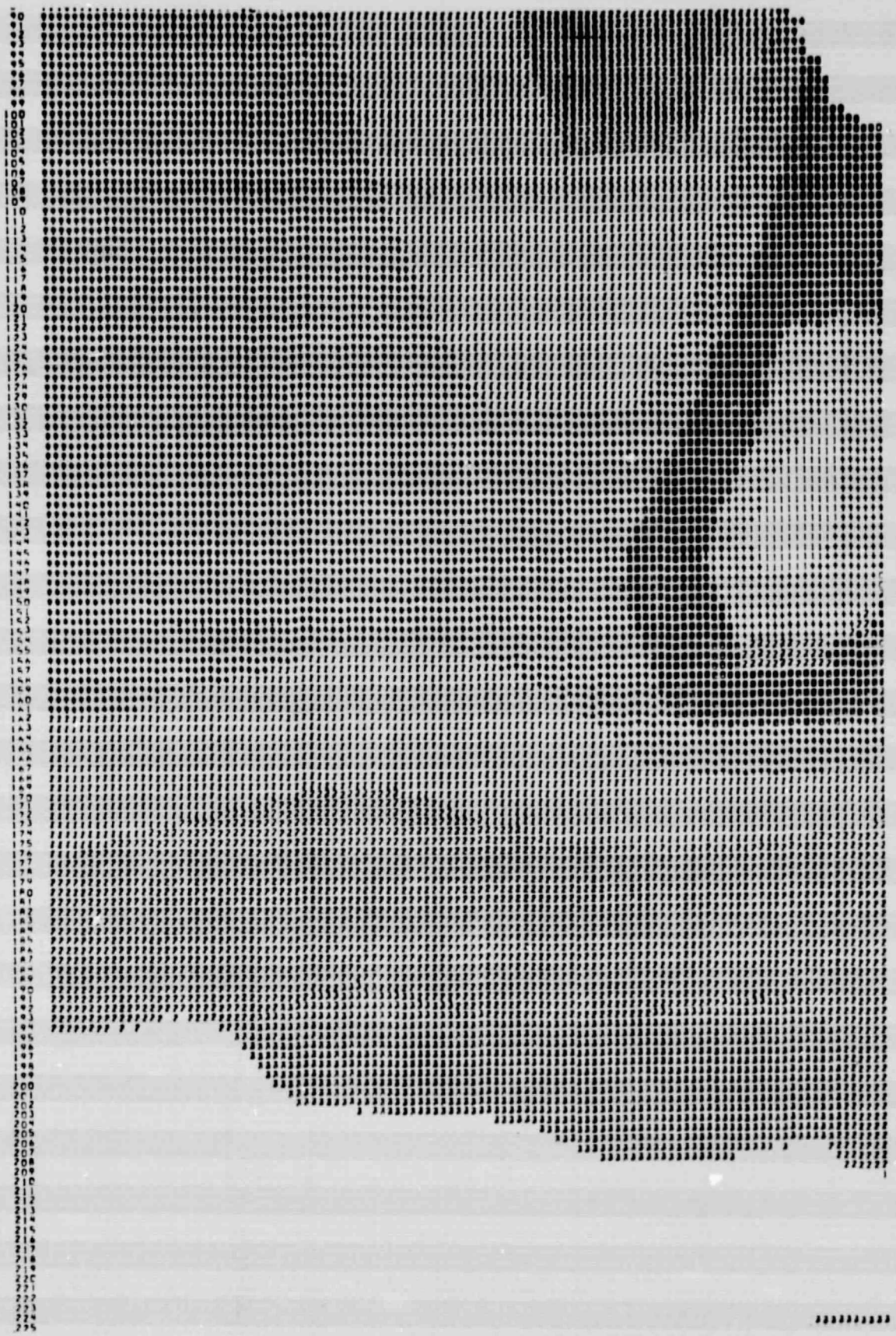


Figure 3g.— Classification results for the artificial image thresholded, with application of three-neighbor filter: Filter applied six times.

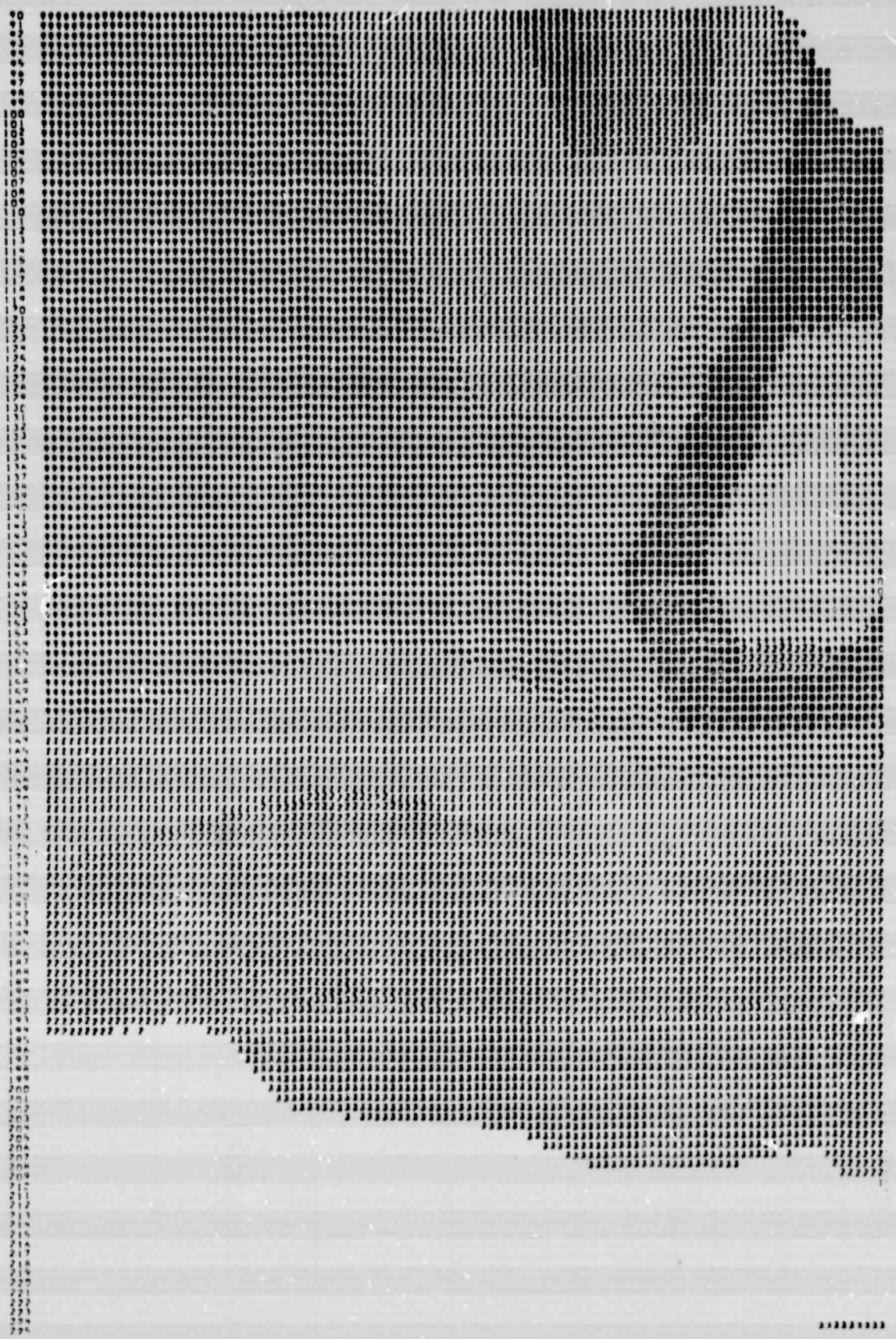


Figure 3h.– Classification results for the artificial image thresholded, with application of three-neighbor filter: Filter applied seven times.

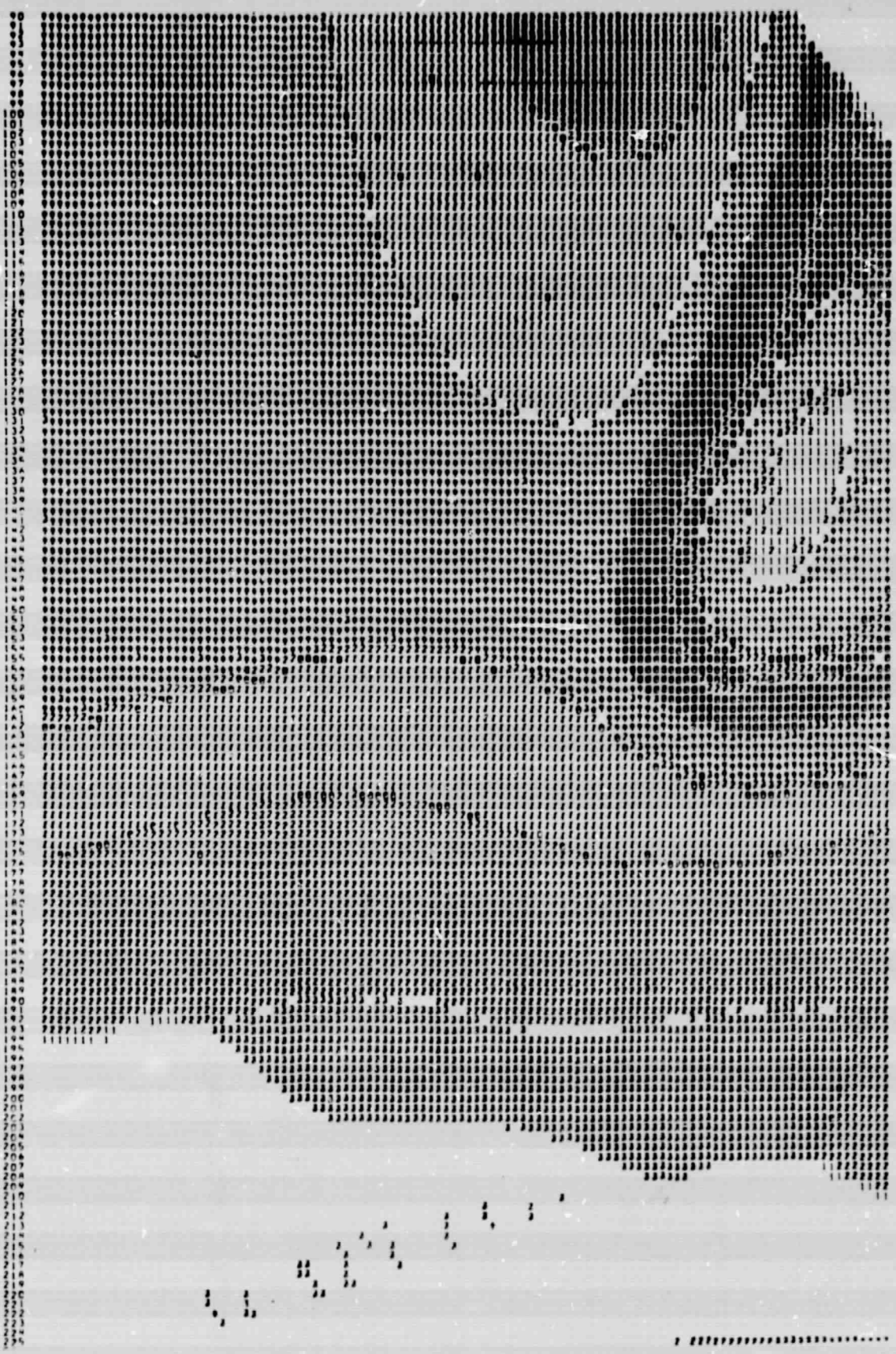


Figure 4a.— Classification results for the unthresholded image before application of the three-neighbor filter.

Figure 4b.— Classification results for the unthresholded image with application of the three-neighbor filter: Filter applied once.

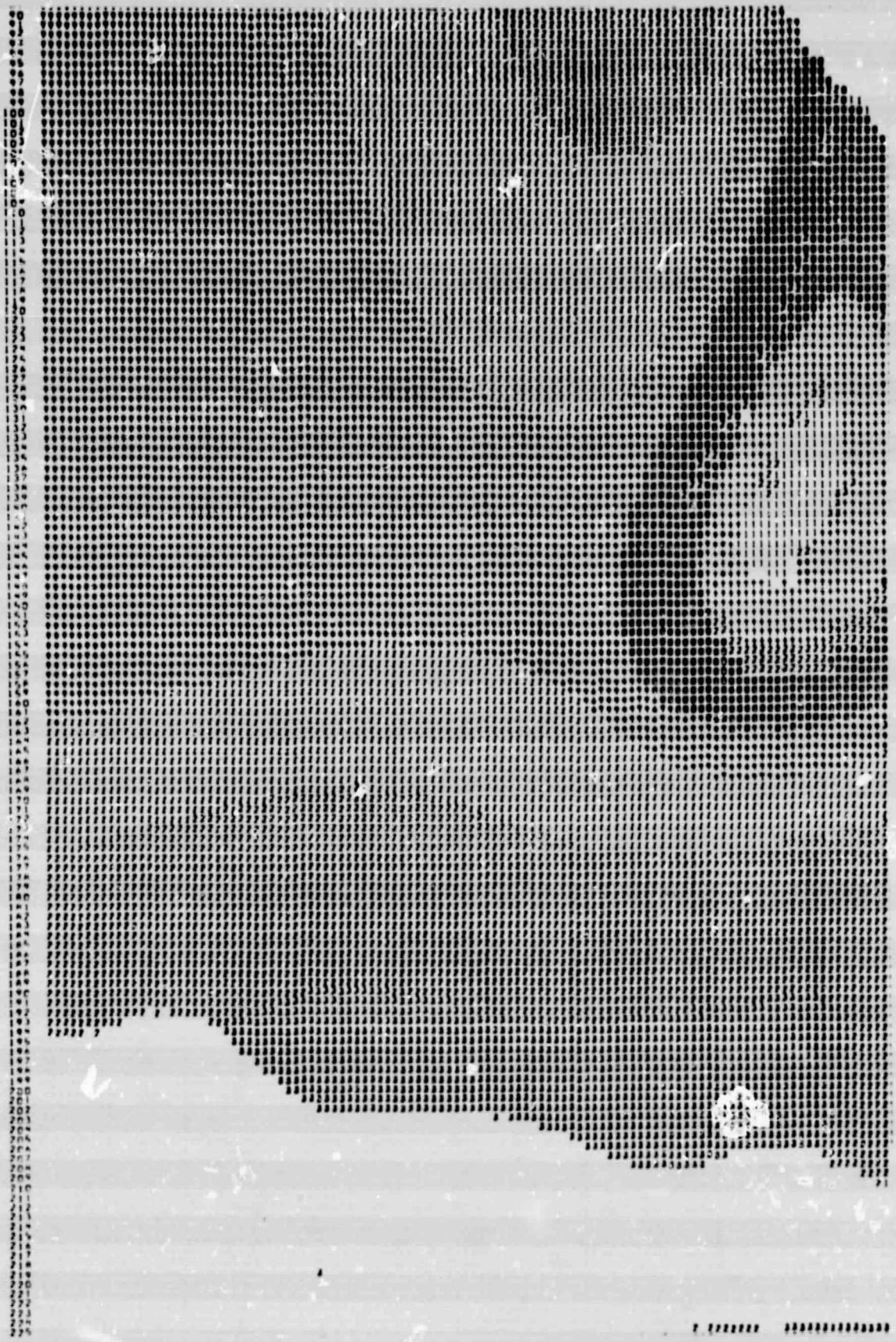


Figure 4c.— Classification results for the unthresholded image with application of the three-neighbor filter: Filter applied twice.

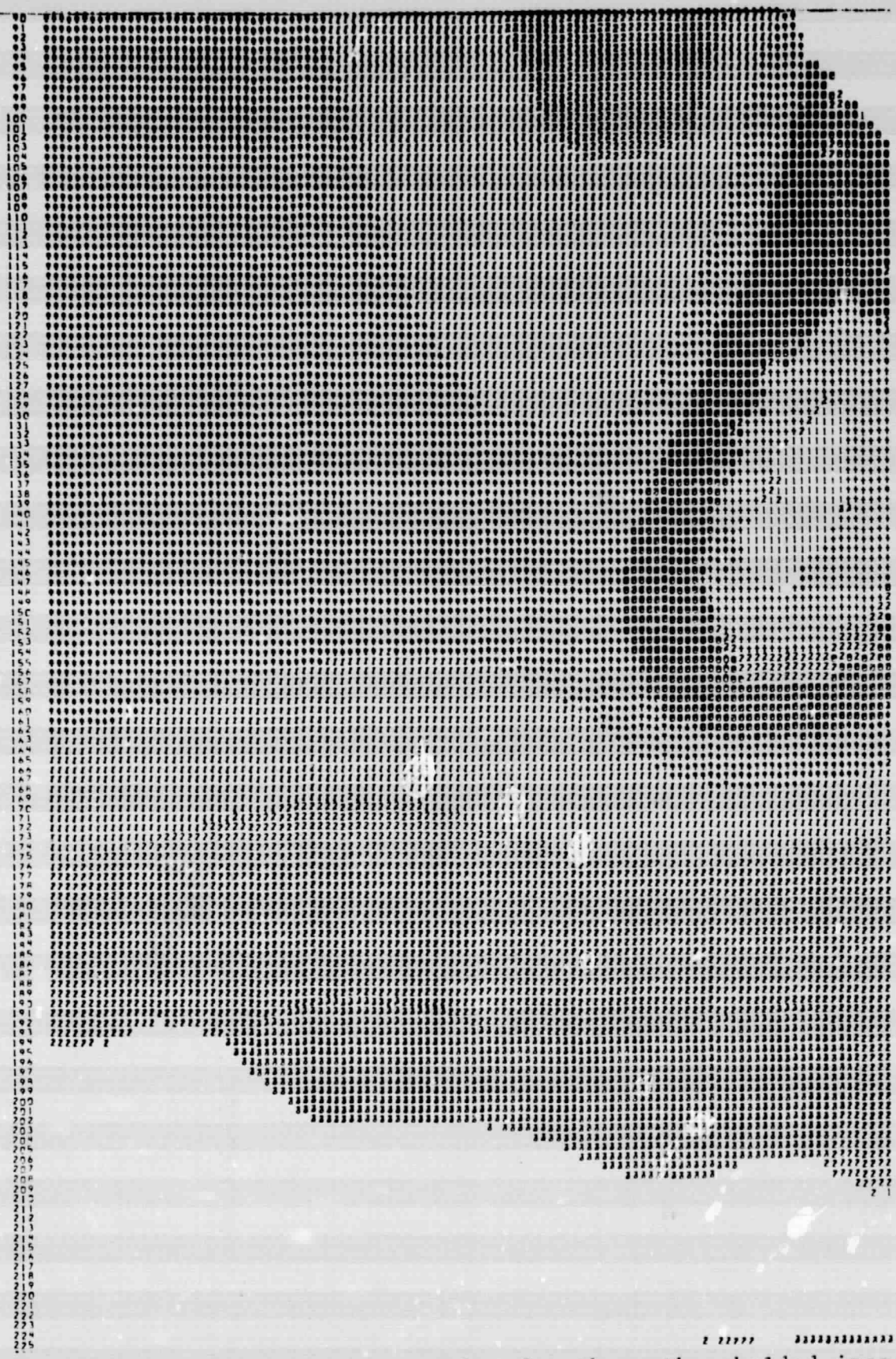


Figure 4d.– Classification results for the unthresholded image with application of the three-neighbor filter: Filter applied three times.

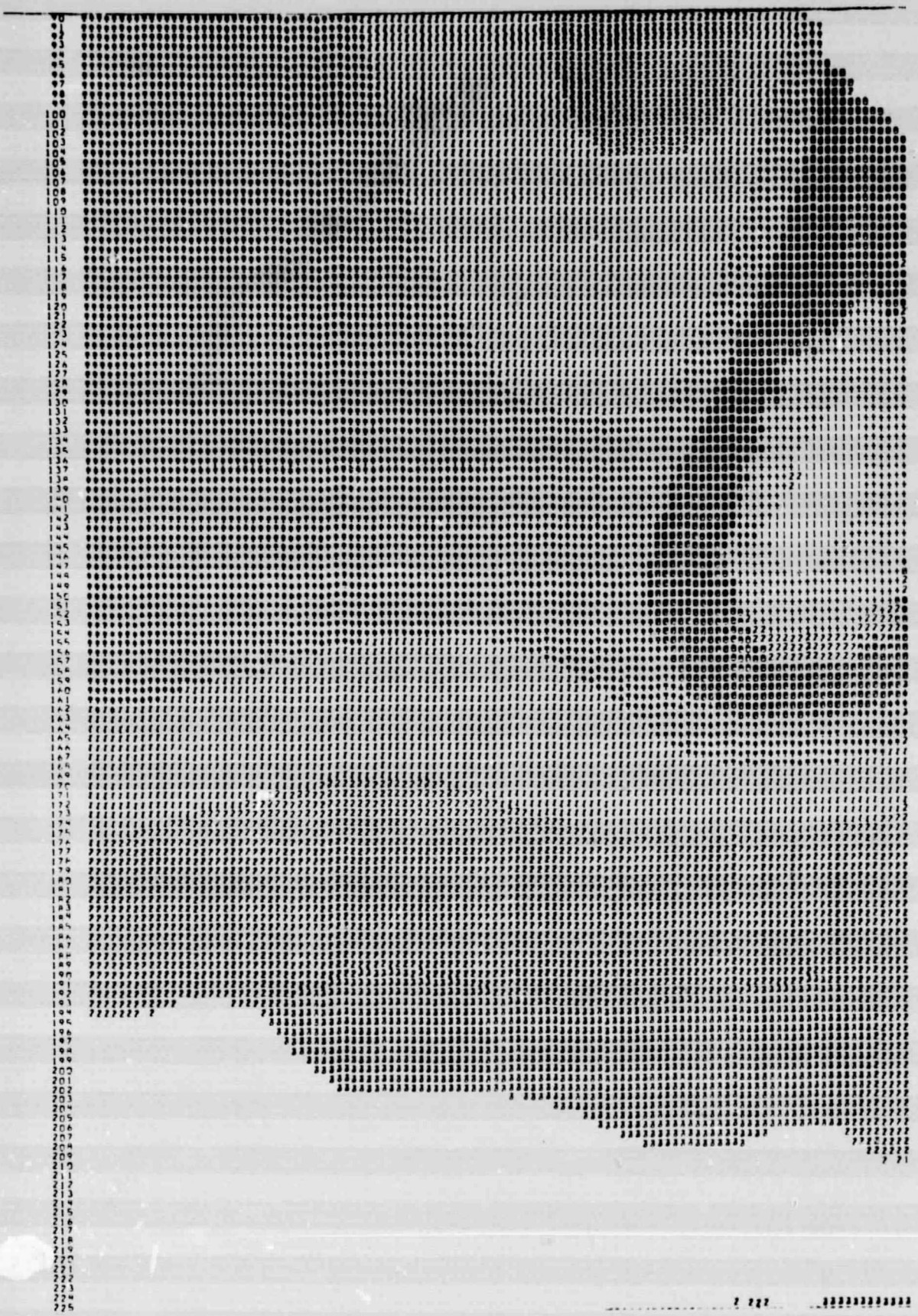


Figure 4e.— Classification results for the unthresholded image with application of the three-neighbor filter: Filter applied four times.

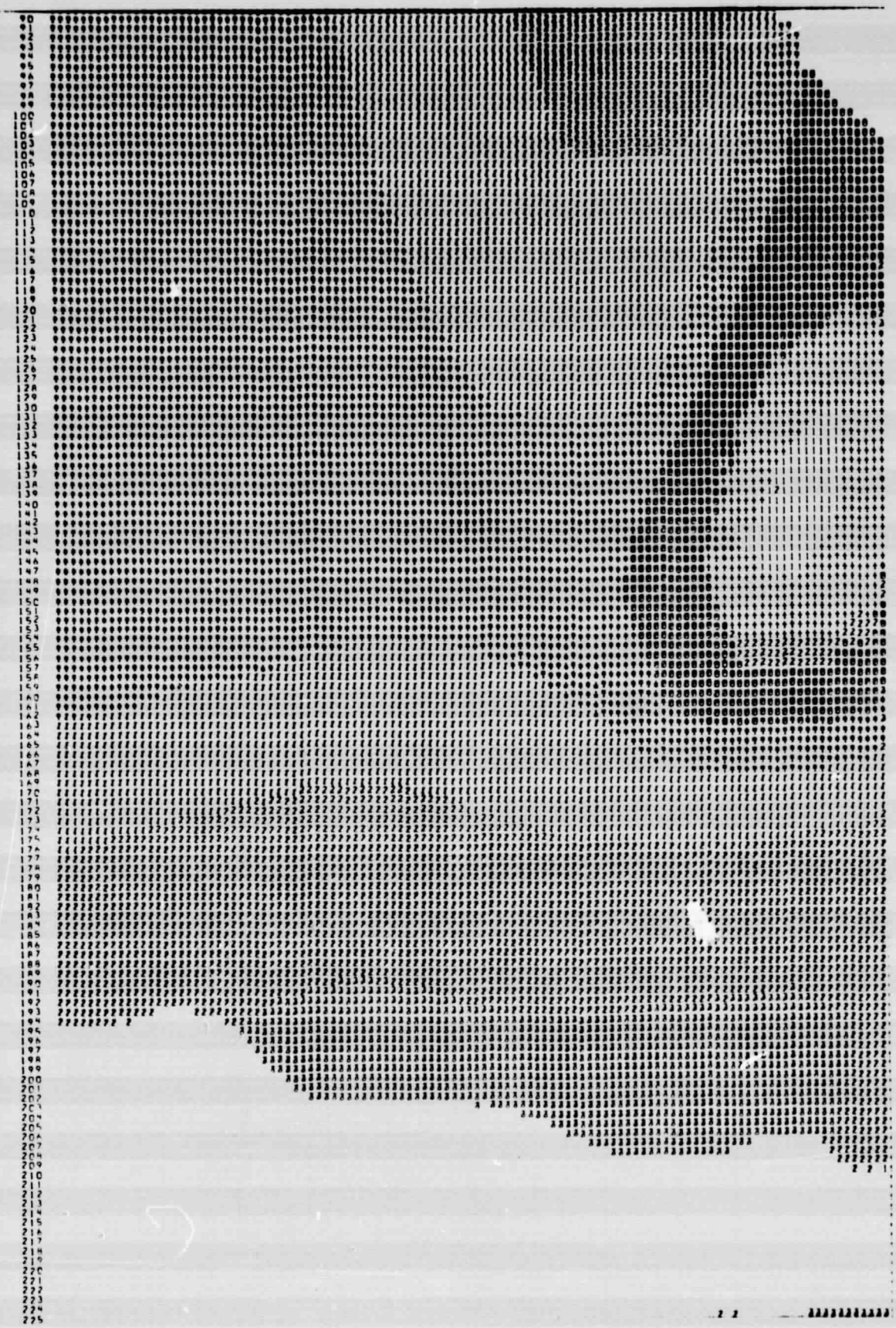


Figure 4f.— Classification results for the unthresholded image with application of the three-neighbor filter: Filter applied five times.

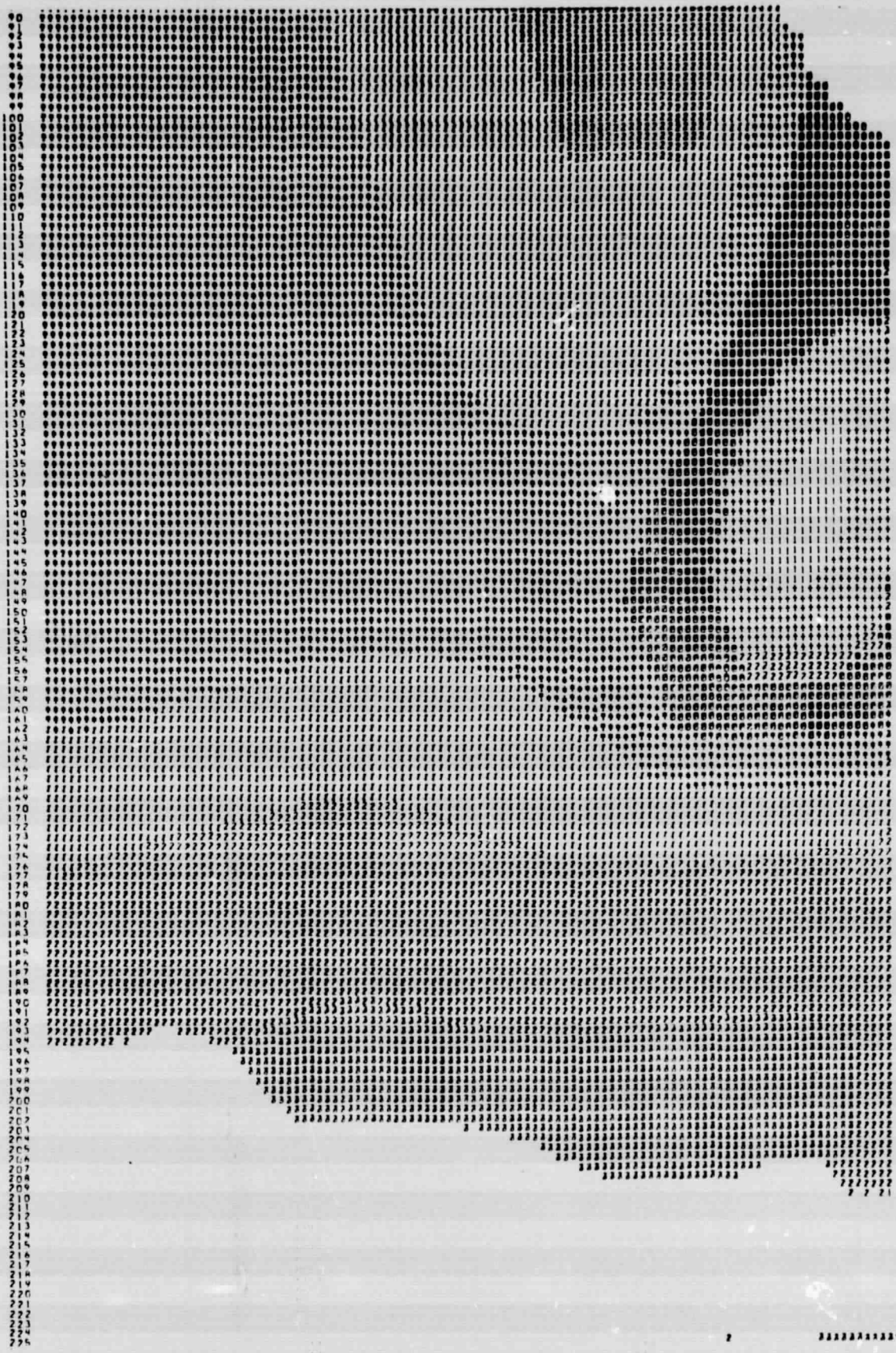


Figure 4g.— Classification results for the unthresholded image with application of the three-neighbor filter: Filter applied six times.

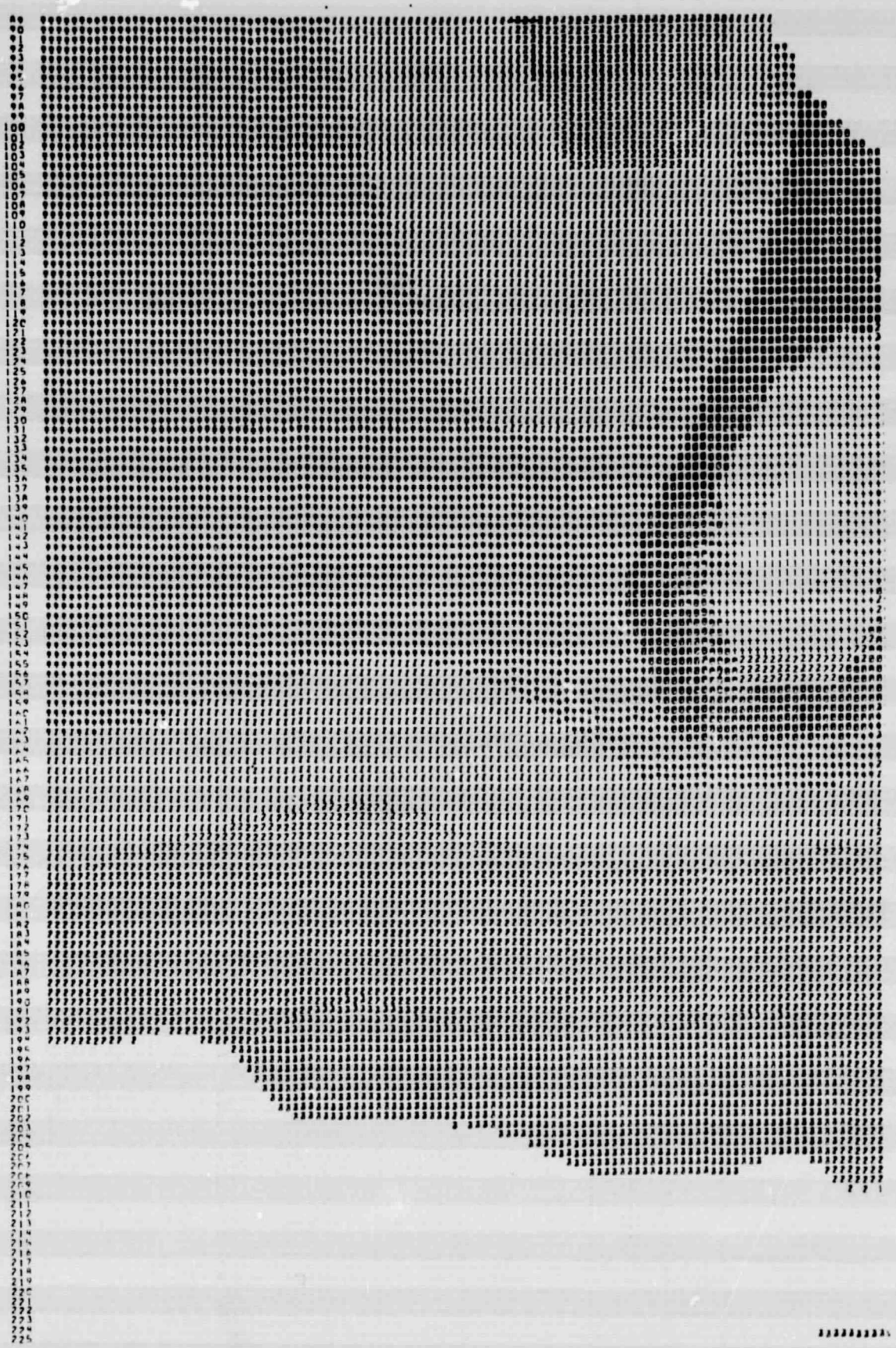


Figure 4h.– Classification results for the unthresholded image with application of the three-neighbor filter: Filter applied seven times.

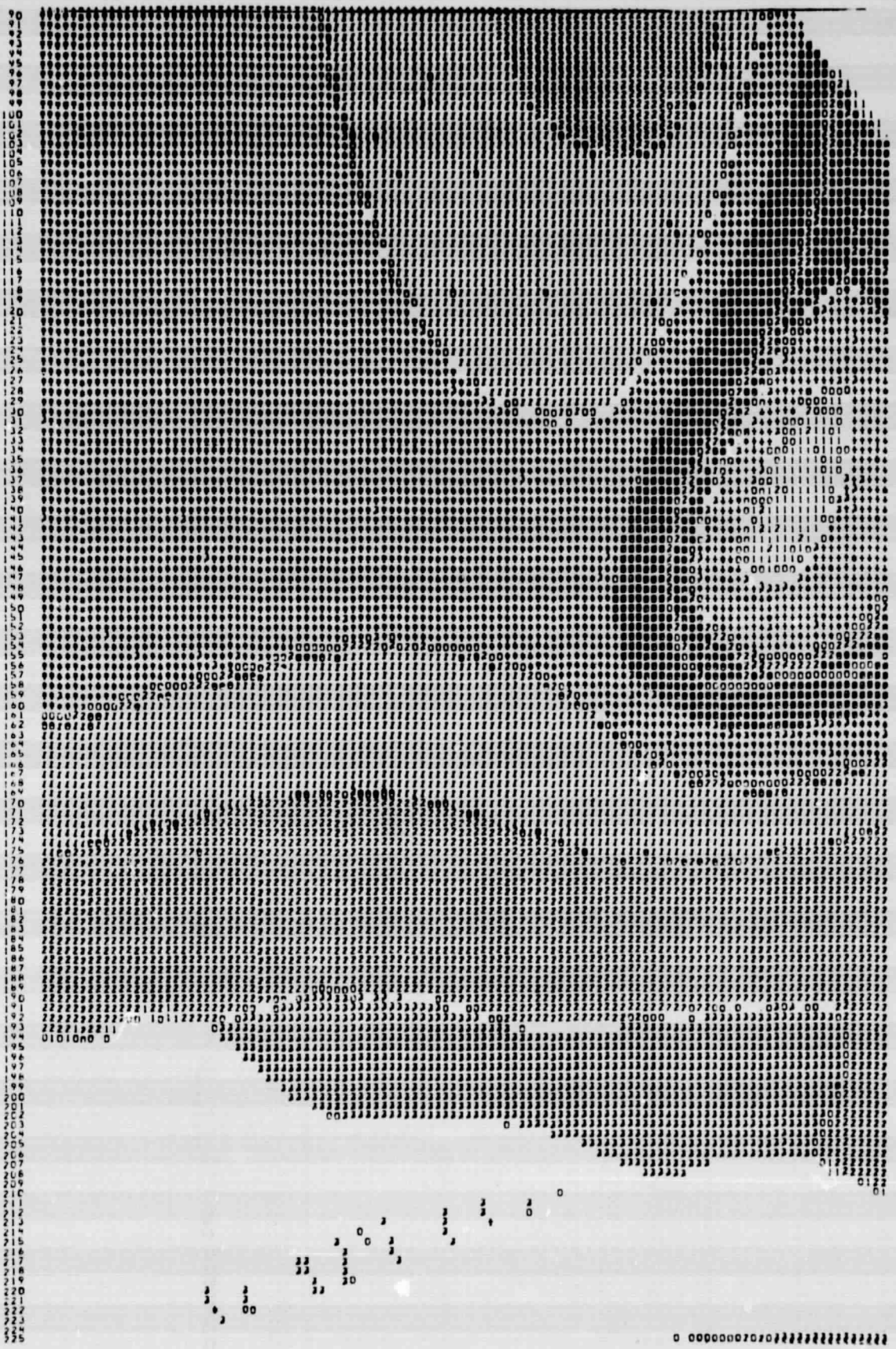


Figure 5a.– Classification results for the image.

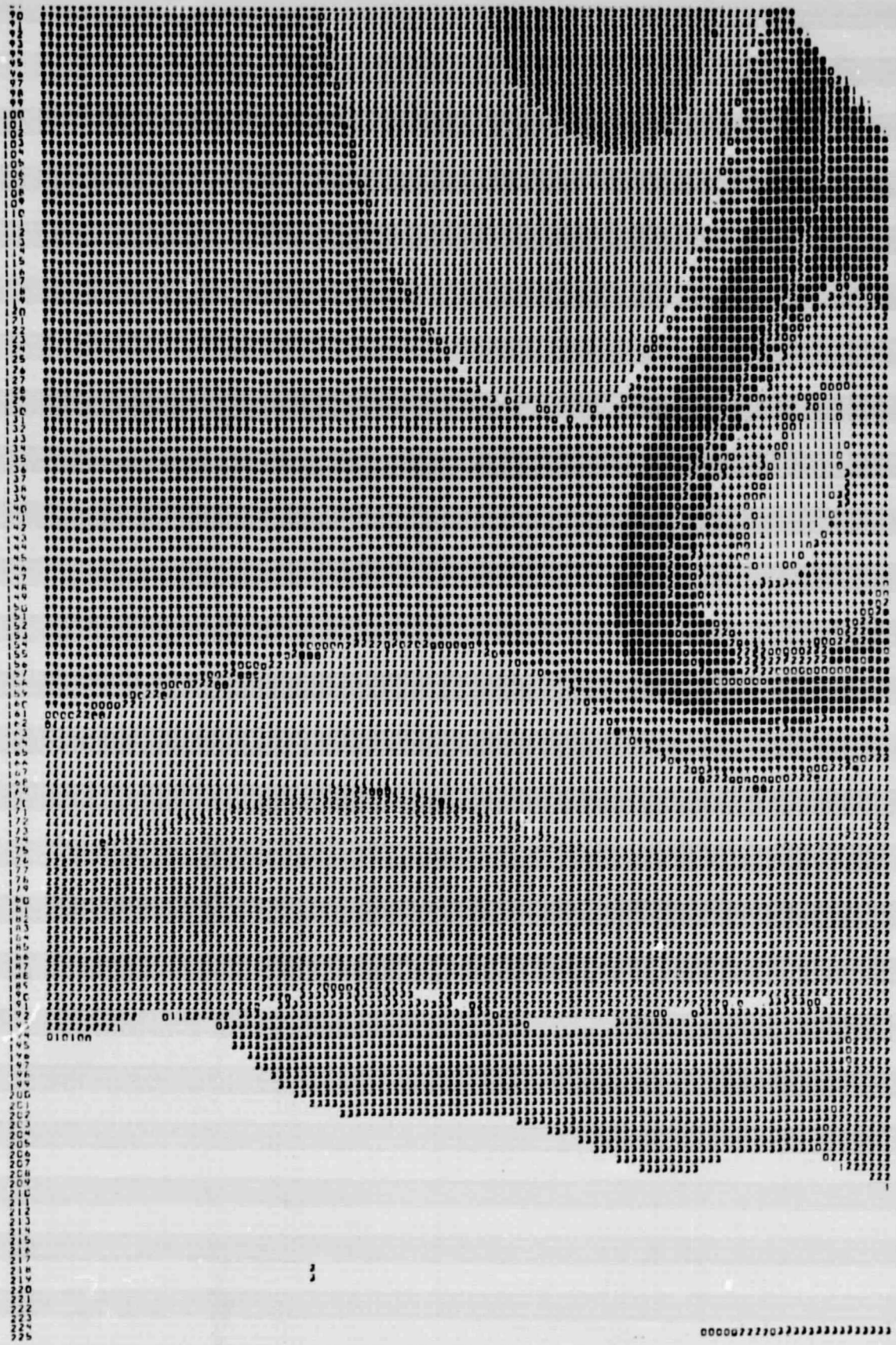


Figure 5b.— Classification results for the image with application of the four-neighbor filter: Filter applied once.

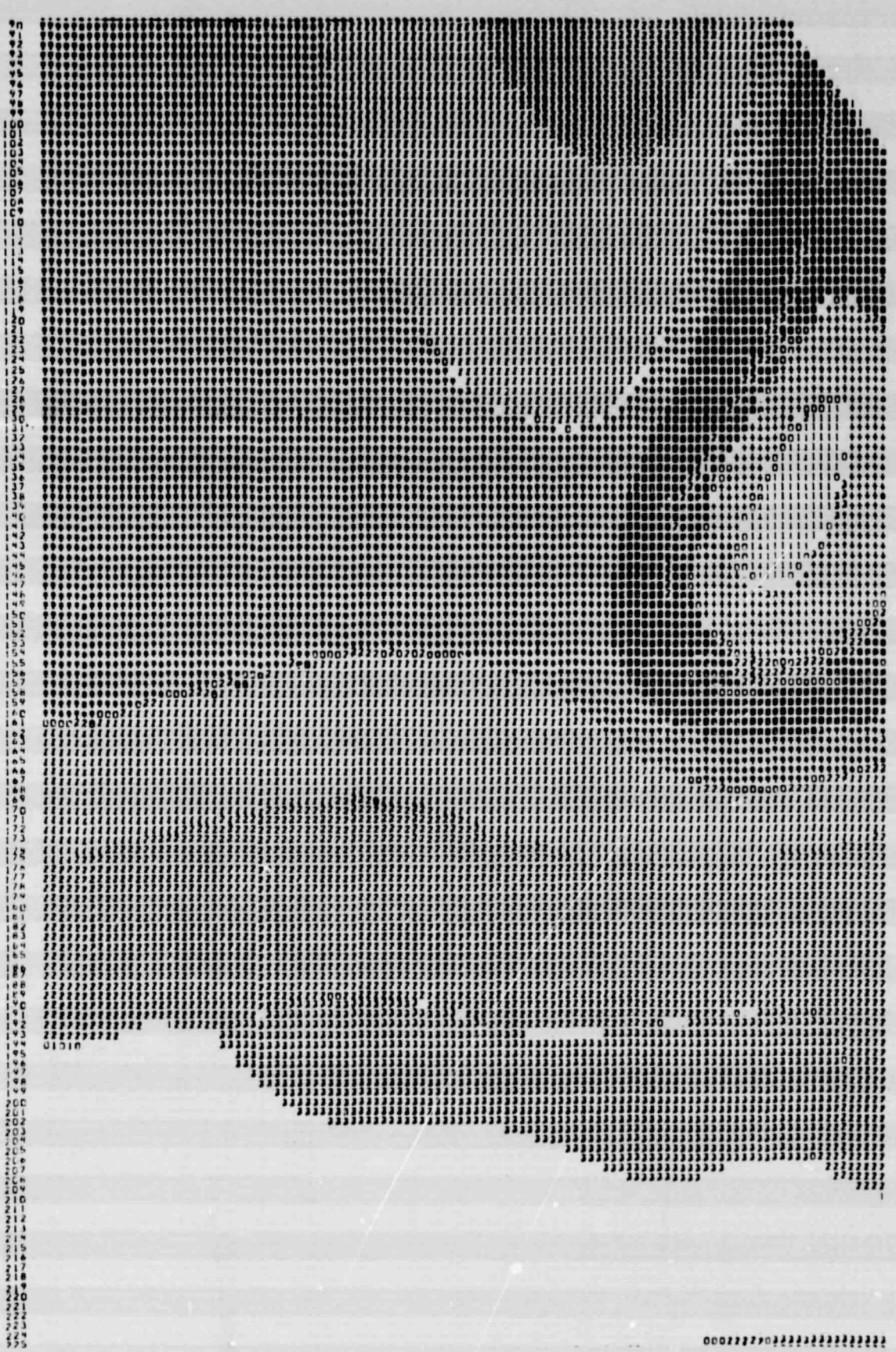


Figure 5c.— Classification results for the image with application of the four-neighbor filter: Filter applied twice.

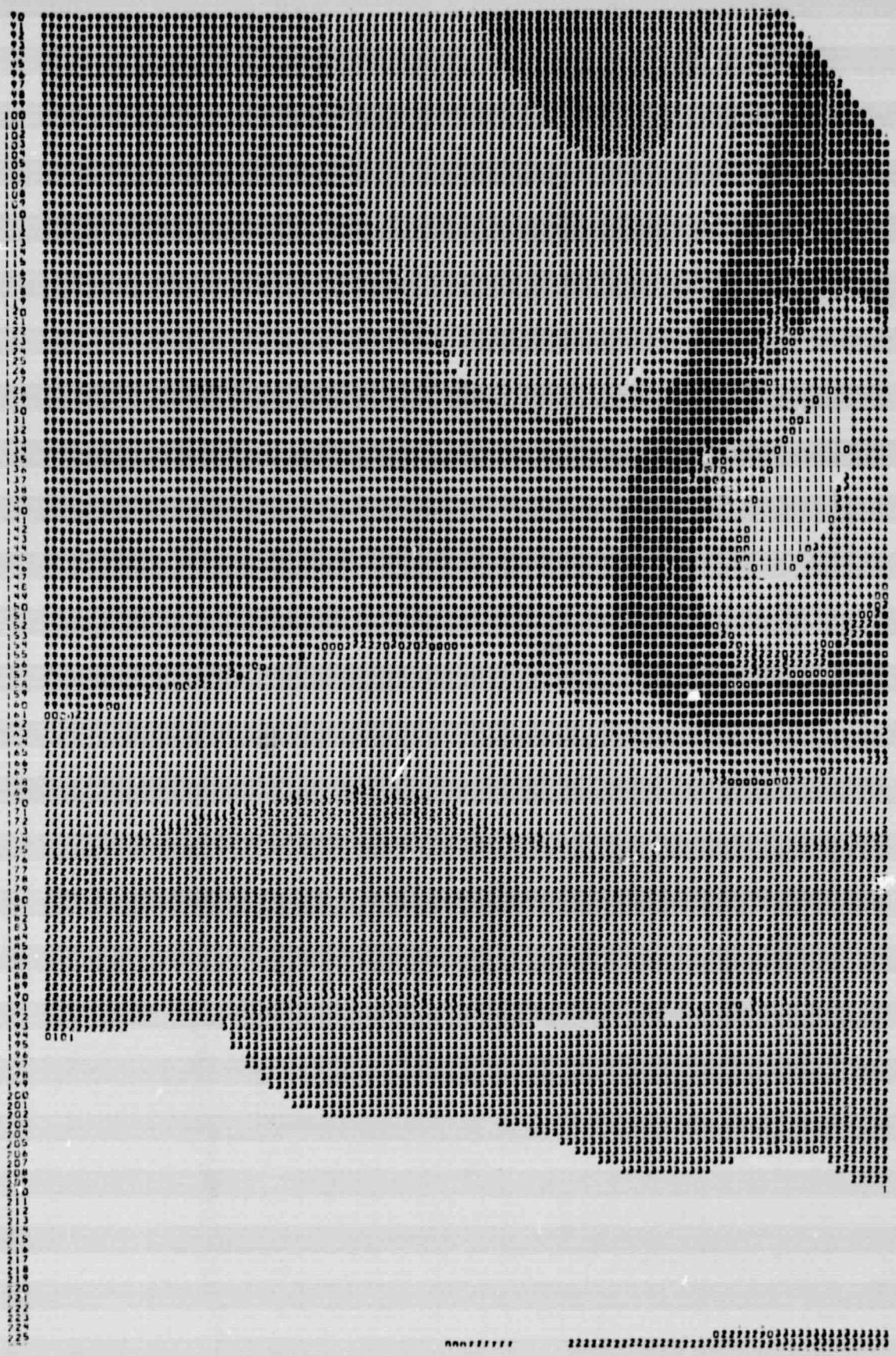


Figure 5d.— Classification results for the image with application of the four-neighbor filter: Filter applied three times.

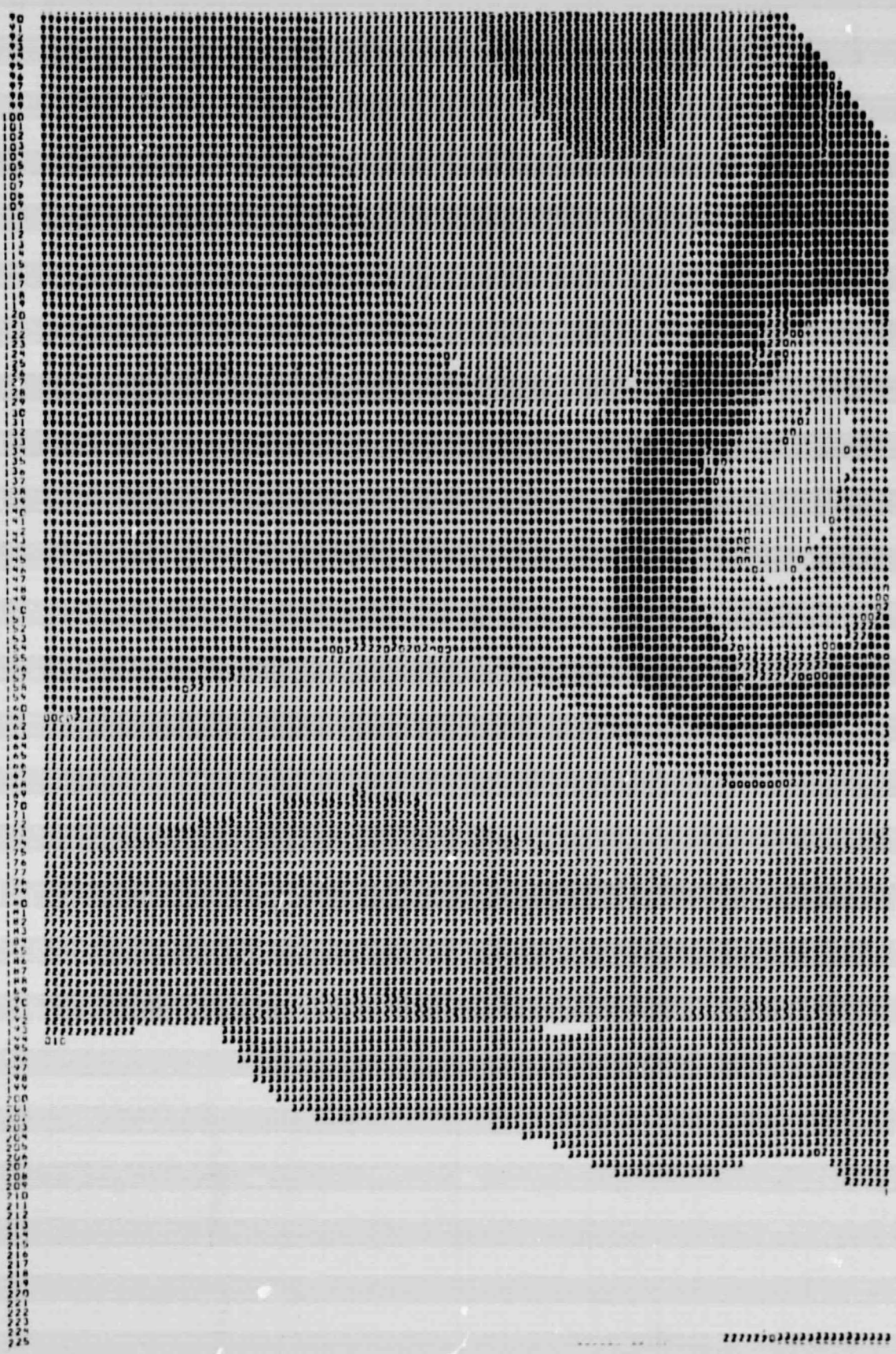


Figure 5e.– Classification results for the image with application of the four-neighbor filter: Filter applied four times.

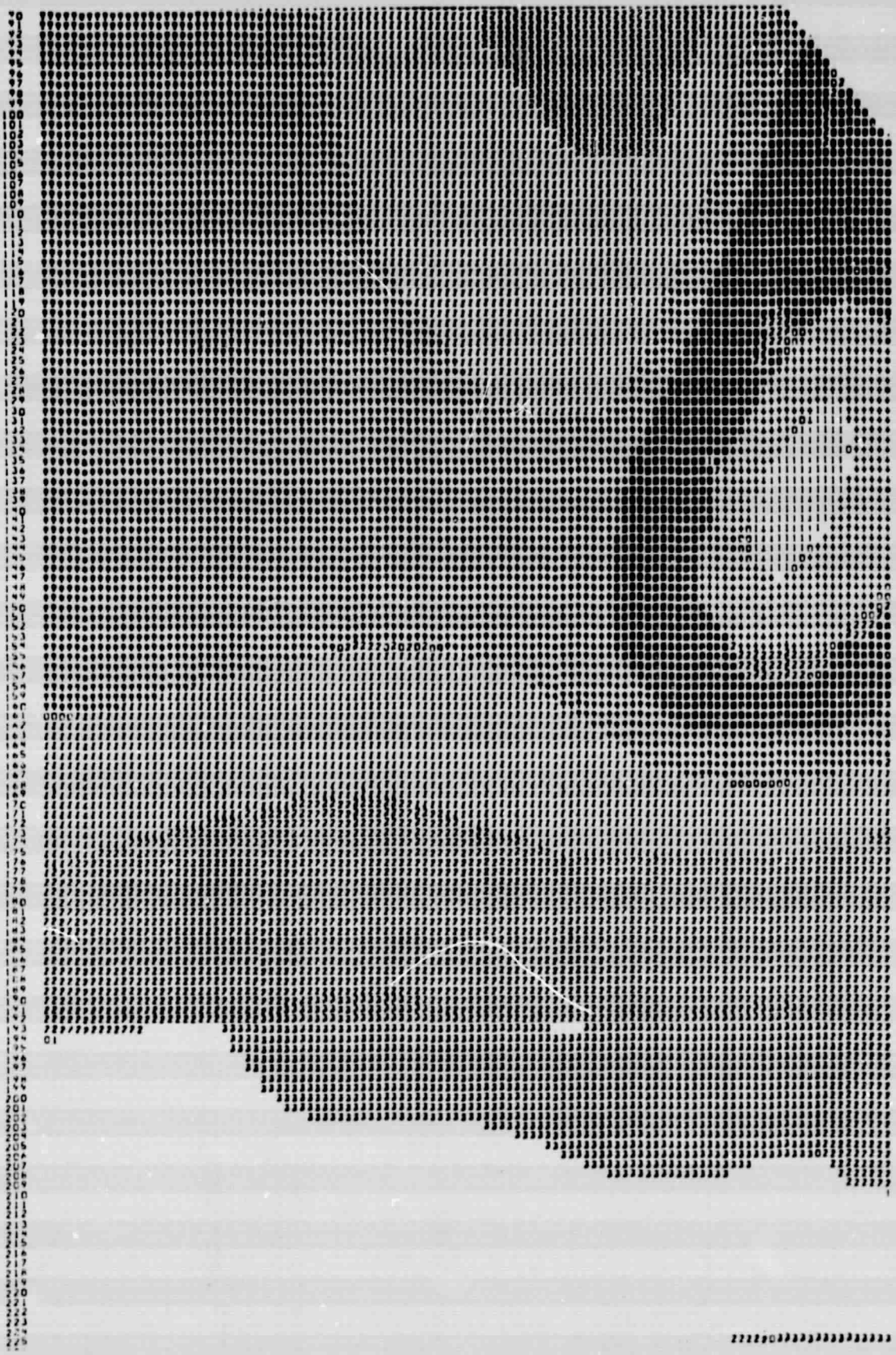


Figure 5f.– Classification results for the image with application of the four-neighbor filter: Filter applied five times.

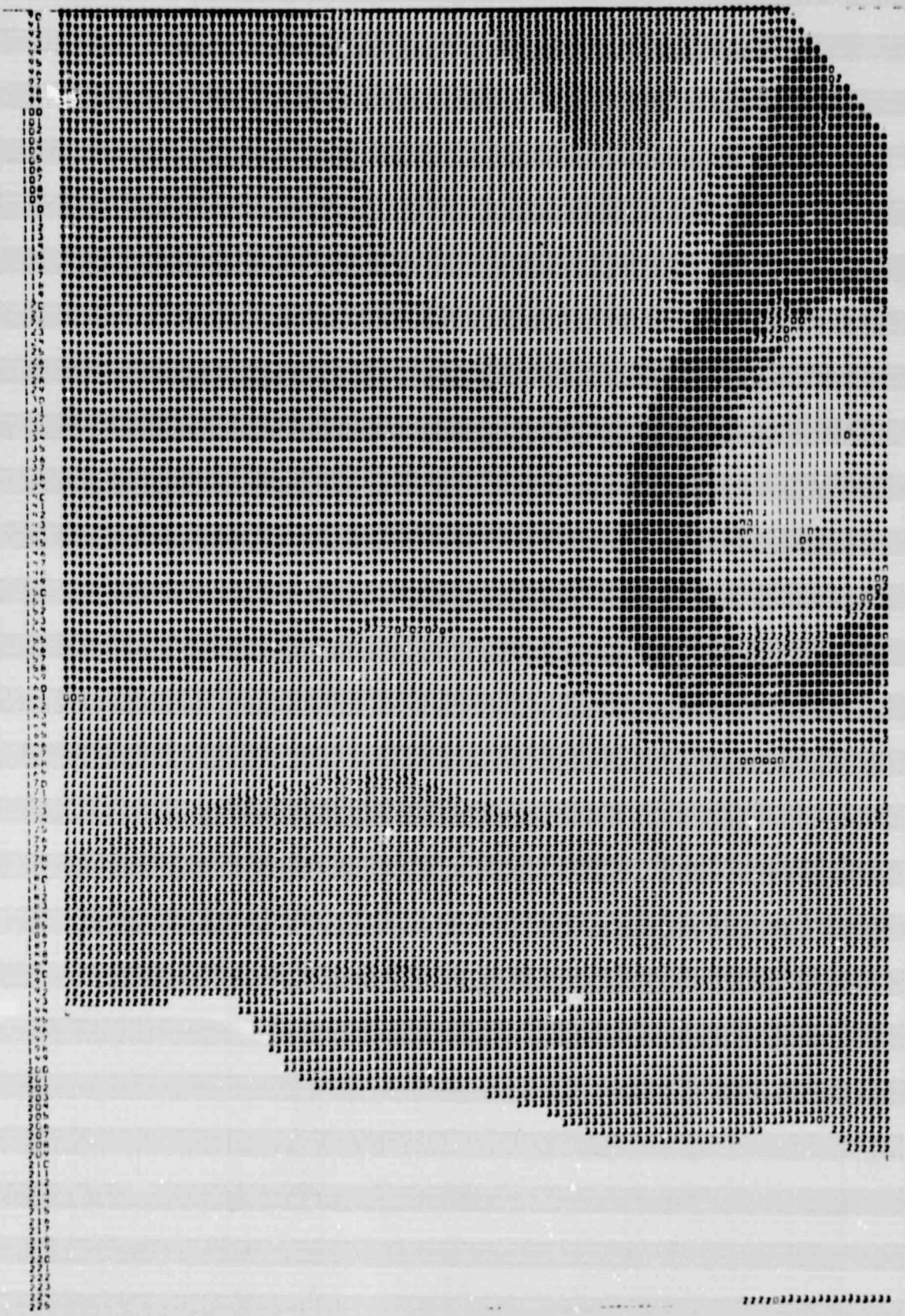


Figure 5g.— Classification results for the image with application of the four-neighbor filter: Filter applied six times.

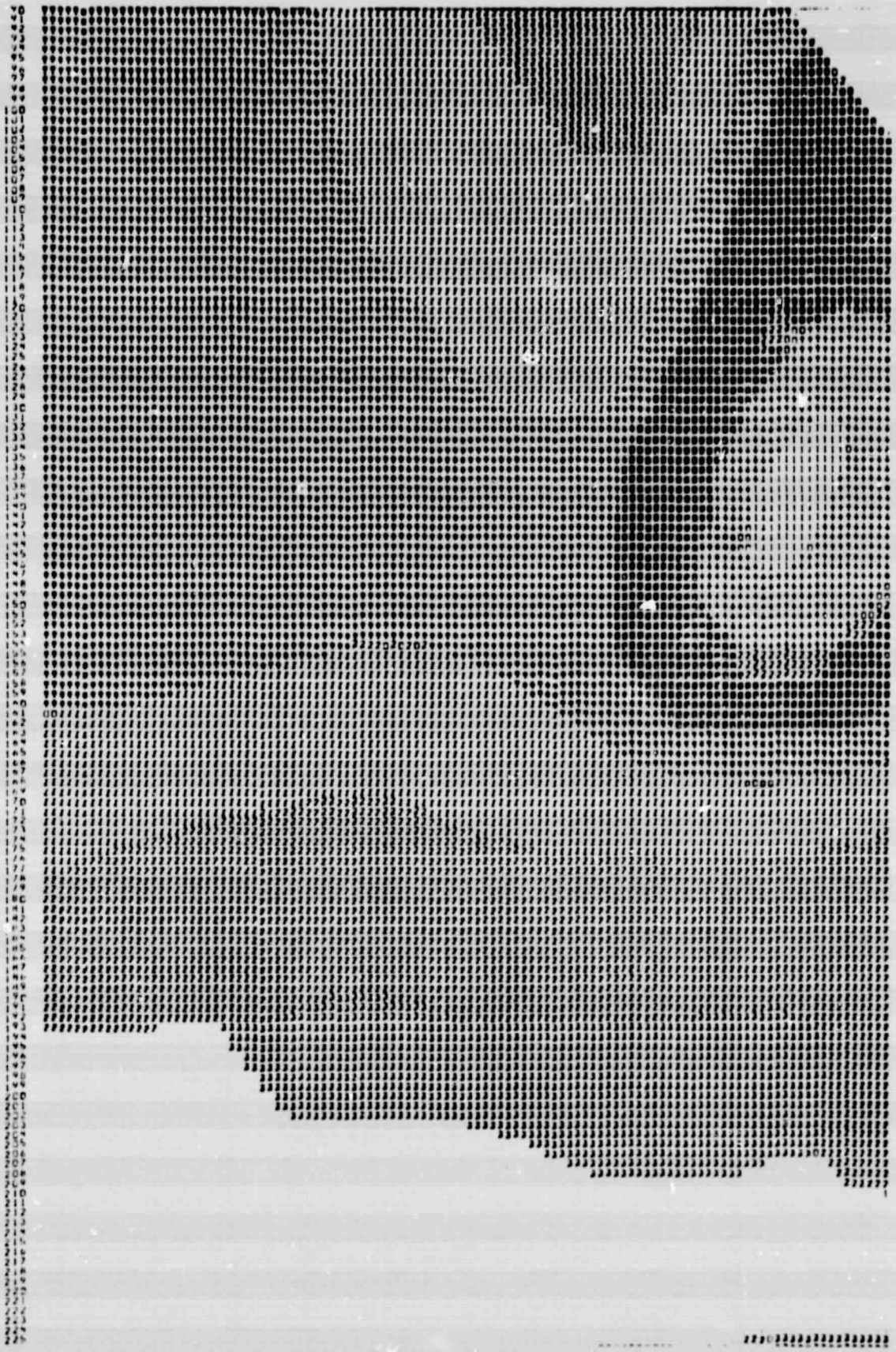


Figure 5h.— Classification results for the image with application of the four-neighbor filter: Filter applied seven times.

Figure 6.– Classification results for the image with seven applications of the five-neighbor filter.

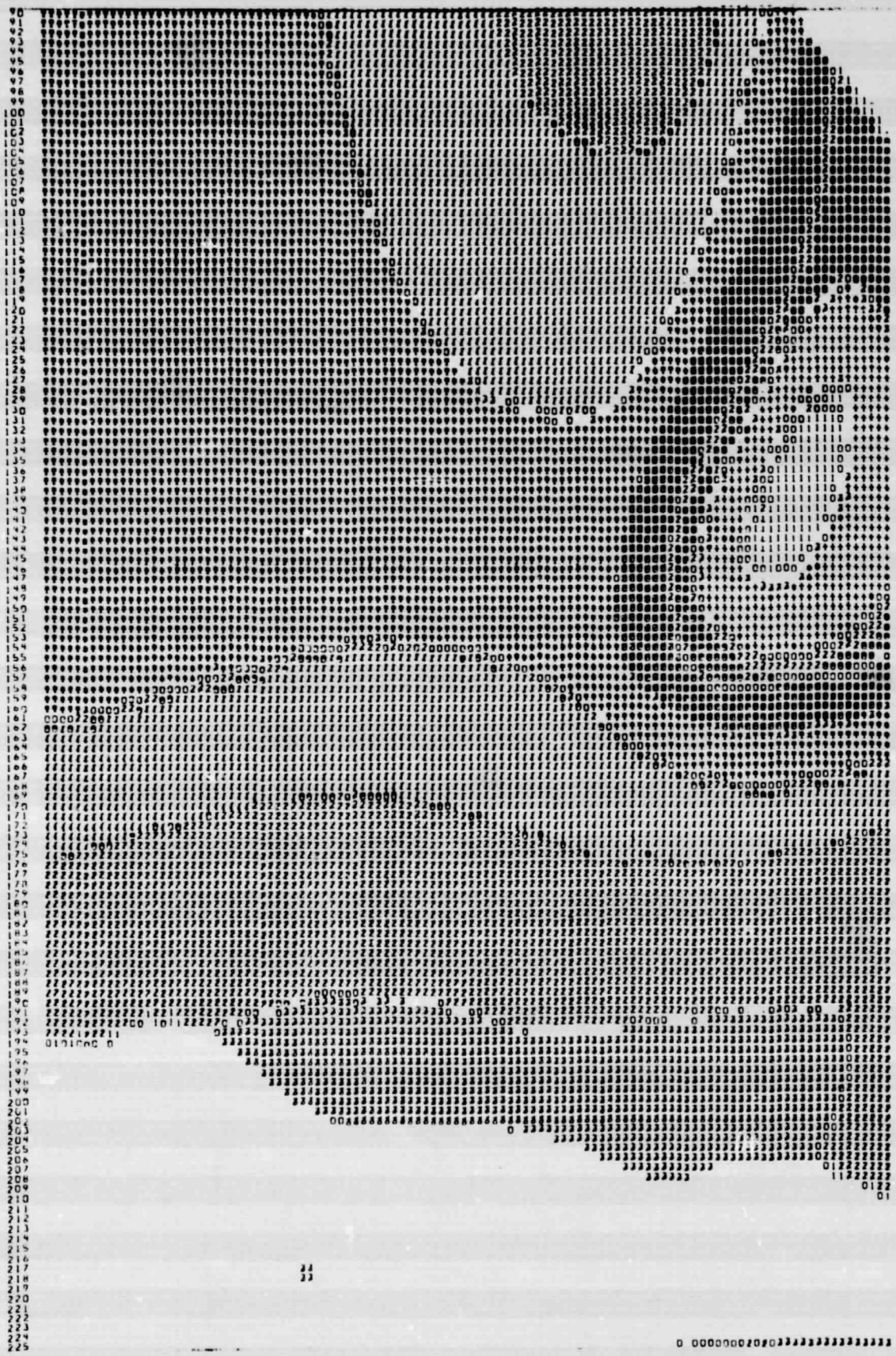


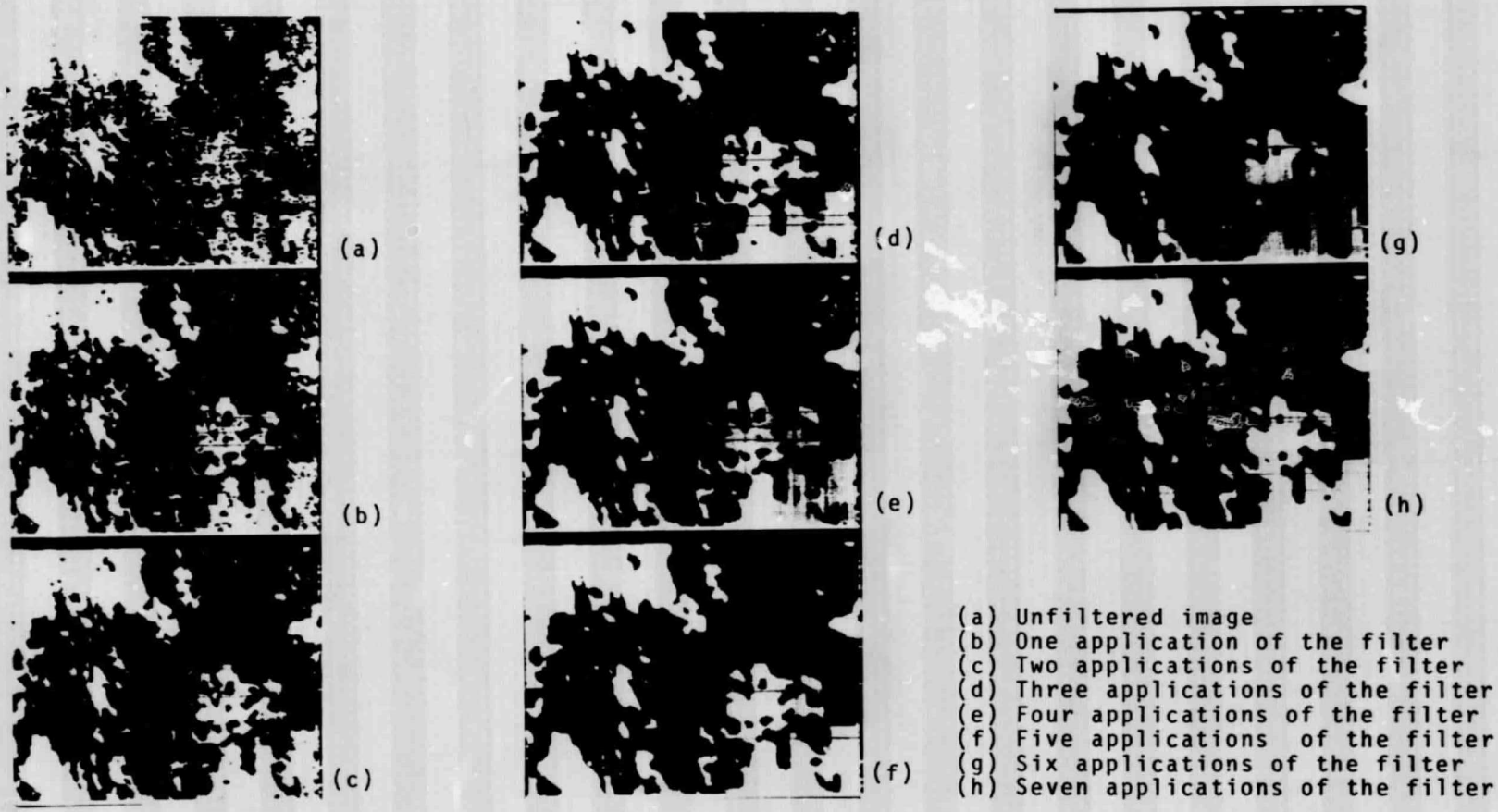
Figure 7.– Classification results for the image with seven applications of the six-neighbor filter.

APPENDIX A

FILTRATION OF RESULTS OF A ZONE DISCRIMINATOR

Arp and Phinney developed an interesting discriminator of reflectivity-thermal regimes (ref. 4). In essence, they extended emissivity zones using results of clustering of composite images from the Very High Resolution Radiometer of ITOS/NOAA satellites.

Figure A-1 shows the effects of filtering a portion of the resulting zone image. Figure A-1 (a) shows the unfiltered clustered image; (b) shows the results of a single application of the filter; (c), a double application of the filter, etc. The user decided that three applications was optimum in this application.



(a) Unfiltered image
(b) One application of the filter
(c) Two applications of the filter
(d) Three applications of the filter
(e) Four applications of the filter
(f) Five applications of the filter
(g) Six applications of the filter
(h) Seven applications of the filter

Figure A-1.— Filtering results of a zone discriminator.

APPENDIX B

FILTERING RESULTS OF CLUSTERING OF A LANDSAT IMAGE

Figure B-1 shows the results of clustering a Landsat image of east-central Mexico. Figure B-1(a) shows the results of a single application of a three-neighbor filter; figure B-1(b) shows the results of two applications of the filter, etc.

In this case, it can be seen that one or two applications may be useful for simplifying the results of clustering, but more applications may be harmful. The river is very apparent in the raw image, but it tends to disappear with multiple applications.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(a) Unifltered image
(b) One application of the filter
(c) Two applications of the filter
(d) Three applications of the filter
(e) Four applications of the filter
(f) Five applications of the filter
(g) Six applications of the filter
(h) Seven applications of the filter

Figure B-1.- Filtering results of clustering of a Landsat image.